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# Gastrodia elata and its Symbiotic Association with *Armillaria mellea*.

BY

S. Kusano.

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With Plates I—V and one Figure in the Text.

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## I. Introduction.

It is more than evident that *Gastrodia elata* Bl., a non-chlorophyllous orchid, is unable to exist as an autophyte. From the analogy with other Orchidaceous plants whose vegetative organs are equally reduced, it may be reasonably presumed that *Gastrodia* is a humus saprophyte showing mycorrhiza, as already assumed by JONOW ('89). Yet no attempt, it is true, has ever been made to give a complete account of the corresponding structures of the subterranean organ. As it seemed to me that an anatomical study of *Gastrodia*, whatever may be the true mode of nutrition, may throw a certain light on the nutritive function of the much reduced subterranean organ, I had once undertaken, about ten years ago, a work on this subject. When I examined a large number of the subterranean parts of this plant, I could find nothing else than numerous tubers at various stages of development. Much to my surprise, a great effort was made quite in vain to establish either their association with fungal mycelia or their absorbing action of soluble matters from the soil. This superficial observation obscured the real habit of this plant, and for the solution of the mystery involved a painstaking study became highly necessary, to which, however, I had no opportunity to devote myself.

It was in 1907 that I was stimulated to reinvestigate this plant by an accidental discovery of a flowering tuber attacked by the rhizomorph strands of a fungus, as is shown in Fig. 13. It was the specimen that convinced me of the mycorrhiza formation: the entangled hyphae from the strands have spread out in the cavity of certain cells of the tuber, but without giving any indication of its parasitic relation. While then I carried out a cytological study in order to make clear the internal relation between the two symbionts, it appeared desirable to make some culture-experiments relating to the biological problems, such as the development and the fate of numerous tubers which are found actually not associated with the fungus. All these studies have brought forth certain remarkable results worth while to present in this paper.

It would be too tedious to repeat in this place the historical review on the mycorrhizal problems, which recent authors (BERNARD, '09; BURGEFF, '09; PEKLO, '10) have already made, but I must mention here the most elaborate works of BERNARD ('09) and BURGEFF ('09), relating to the mycorrhiza of the Orchidaceae. Both authors attempted to isolate the mycorrhizal fungi from the root, and after carrying out several experiments obtained many interesting results on the biology and organization of the mycorrhiza. The present study will perhaps add something to our knowledge on the Orchidaceous mycorrhiza recapitulated by these authors, and further on the symbiotic relation of holosaprophytes to fungi.

The material for the cytological investigations was obtained partly from the field and partly by culture, and was fixed in FLEMMING'S or KEISER'S solution and stained with FLEMMING'S triple stain, HEIDENHEIN'S iron haematoxylin, fuchsin iodine green, and a combination of methyl green and ruthenium red, or of haematoxylin and congo red.

In this place I wish to express my sincere gratitude to Prof. S. Goro, to whom I am greatly indebted for material which was very valuable to me in drawing the general conclusions given in this paper.



## II. Description of *Gastrodia*.

### 1. HABIT.

*Gastrodia elata* is an orchid widely spread throughout Japan and so common in the vicinity of our College that a sufficient material for observations and studies was easily available. It is found growing in the humus soil, mostly in woods. As a noteworthy fact, it vegetates predominantly under *Quercus serrata* and *Q. glandulifera*. At one time I found it in the Botanical Garden of our College, flourishing under *Sterculia platanifolia*. In Nikko a few flowering individuals were found on a grassy field where no living tree but some small shrubs were found. However, the observations at several places show its proper habitat to be woods chiefly composed of the above mentioned oaks. This fact gives an idea that this orchid might bear a certain direct or indirect relationship to these trees.

In Tokyo the inflorescence-axis appears above ground regularly at the end of May. It is long, slender, erect, and brick-reddish, attaining at times a height of one metre or more. Racemose flowers (Fig. 2) densely arranging on its upper portion give to the axis an arrow-like appearance (BLUME, '58). Digging them out carefully in the flowering season, we can find always a large number of young tubercles lying near the flowering tuber, the smallest ones measuring 2 mm. in diameter. The flowering tuber, the full grown one, is oblong and slightly curved, attaining without almost any exception 10-17 cm. in length. This tuberous rhizome is the representative of the whole vegetative body of *Gastrodia*, whereas it may be acknowledged as a most reduced form of orchids, as JONOW ('89, p. 489) has already noted.

In my experience, it is a curious fact that in spite of the occurrence of young tubercles near the flowering tuber, in most cases no flower-shoot appears at the same place in the next year, but at quite an unexpected place. It seems to me also strange that the number of flowering tubers is exceedingly few compared with the number of sterile tubercles. These facts seem to lead us to the view, though incorrect, that the tubercles would

attain to the flowering stage one by one after several years' growth at the cost of organic nutritive substances taken up by them.

One who makes field observations only in the flowering season would perhaps find no evidence against this view. At other seasons it might be possible to find some tubercles symbiotic with the fungus. However, if we bear in mind that such a case is in fact exceedingly rare, a great majority of tubercles being in any season always free from the fungus, we would hesitate to assign the proper nutrition and normal development of *Gastrodia* entirely to the co-operation of the fungus. Notwithstanding, the truth of this method of obtaining food can no more be doubted from the results of culture-experiments, which further brought to light the fate of the young tubercles.

## 2. STRUCTURE OF THE TUBER.

The tuber is first covered with scale leaves developed from the nodes. They are short-lived, and by the increasing dimension of the tuber they are soon stretched out into a thin membrane. Afterwards, in either young or old tubers, they become fragmented, except those over the growing apices, and stripped off from the surface of the tuber.

Like potato-tubers, the tuber of *Gastrodia* produces on its surface fragmented thin membranes of a corky nature, which are easily stripped off, new ones being formed successively beneath them. The development of the cork tissue seems to render the entry of aqueous solutions into the tuber highly difficult. Therefore, the access of any nutritive substance into this plant through its underground portion is inconceivable, so that it cannot be ranked to those orchids, such as *Wulfschlaegelia aphylla* (Johow, '85) and *Cephalanthera oregana* (MacDougal, '99, p. 2), whose absorbing organ is assumed to permit the passage of organic food-substances through its surface. This fact calls attention to the problem as to how the isolated young tubercles can derive their nourishment from outside. As to their ontogenetic origin we may easily judge from the presence of the attachment surface on their basal end (Figs. 8, 13), on which a remnant of the decayed tuber is often found, that they are offsets of a mother-tuber, with which

their nutritive connection has been interrupted during the developmental stages. The chief points we desire to know are their subsequent mode of both nutrition and development.

The tuber, a reservoir of reserve material, consists essentially of parenchymatous cells. For means of orientating the mycorrhizal cells as mentioned below we may divide them conveniently into three layers, viz.:

First layer. This is a peridermal layer developed in the usual manner. It is composed of cork-cells, rectangular or flattened, and regularly arranged as usual. In the growing tuber the outer portion of this layer is stripped off as a thin membrane (Fig. 17 *a*).

Second layer. It is composed, under the phelloderm, of a few layers of round or polygonal, nearly isodiametrical parenchymatous cells. The diameter in the tangential direction is nearly equal to that of the cells of the first layer. Generally, the size increases progressively towards the inner cells (Fig. 17 *b*).

Third layer. The remaining inner cells of the tuber may be included in this layer (Fig. 17 *c*). In an old tuber it is distinguished from the second layer by the larger size (nearly twice larger in diameter) of the composing cells. The inner portion of this layer is traversed here and there by small vascular bundles.

In tubers somewhat advanced in growth the cell wall slightly thickens and makes its pits clearer (Fig. 17 *w*). The thickening of the wall is, however, less conspicuous in the inner portion of the tuber.

In a flowered tuber the central ground tissue collapses and forms a hollow space, and this hastens the death of the tuber.

In autumn a large amount of reserve material is accumulated in all parenchymatous cells, which flows out from the cut surface of the tuber as a viscous fluid. The essential components of this fluid are soluble and insoluble carbohydrates. The former reduces easily Fehling's solution, while the latter are fine granules precipitating with difficulty in water. The granules occupy the whole cell cavity as an amorphous mass, but typically they are aggregated loosely into compound grains of subglobular form. The reaction towards iodine shows their being such a starch as is



usually found in non-chlorophyllous saprophytes of the Orchidaceae and other families (GROOM, '95 a, p. 192, '95 b, p. 334; JANSE, '97, p. '79; FIGDOR, '97; MAGNUS, '00; refer also CZAPEK, '05, p. 394). In *Gastrodia* they give the following characters:

1. In fresh material, alcohol specimen, and microtome section the granule gives reddish brown colouration by iodine (alcoholic solution of iodine, chlorzine iodine, and potassium iodide-iodine). By heating the colour disappears and by cooling it reappears. It may be noted that with chlorzine iodine the colour is more intense, while with alcoholic solution of iodine it is more brownish (see MEYER, '95).

2. The milky fluid becomes translucent and pasty by heating. The iodine reaction of this paste gives violet or bluish violet, in a diluted state somewhat reddish violet colour.

3. Under high magnification the granules appear irregularly polygonal. Each granule measures 1.6-0.8  $\mu$ , while the compound grain may attain to  $0.025 \times 0.85$  mm. or 0.035-0.04 mm. in diameter.

4. By the polarisation microscope we can see, though faint, that the granule is optically active.

5. The structure and colour reaction of the starch occurring in the flower organs are the same as in the tuber.

We find in the amyloplast a problematic body. In the peripheral tissue of the tuber the amyloplast not containing starch granules is seen as a spherical body with distinct wall, containing a heavily staining spot (Fig. 37). Accompanying the enlargement of the amyloplast due to the accumulation of starch granules, the spot increases in size, attended by several alterations in structure. It appears sometimes as a resting nucleus having a few chromatins (Figs. 38, 42 a b). It becomes then homogeneous in consistence and is flattened into a disc with faintly staining space in the centre showing vacuole (Figs. 39, 40). There occur sometimes numerous vacuoles (Fig. 42 c). The disc-shape is perhaps due to compression of a bladder which this body has assumed, as the latter form is seen in most of much enlarged amyloplasts (Fig. 42 d).

These forms of the problematic body are in view successively from the

peripheral to the inner cells till about the mycorrhizal cell regions. In almost all deeper-lying cells the amyloplast, having considerably enlarged, does not contain such body (Fig. 41).

The body in question does not seem, to judge by these characteristics, to be identical with either a crystalloidal body or a pyrenoid. As for its real nature we must await further study. At present we can state only that it is optically inactive, and towards several reagents and stains it gives a reaction like a nuclear body, in which a colouring matter characteristic to this orchid is contained. In fact the same body develops more prominently in the peripheral tissue of all the aerial organs where the colour is more intense than in the tuber<sup>1</sup>.

### III. Infection of the Endophyte.

#### 1. MANNER OF INFECTION.

When the tuber is attacked by the rhizomorph strands, certain internal cells of it become infected by the hyphae. The internal hyphae and external strands are connected by means of a thick lateral branch given from the strands. On this account the infection must be of an unusual type, since in an ordinary endotrophic mycorrhiza, the infection is as a rule effected by a single hypha which perforates the outer wall of the epidermis, but causing no apparent injury to the penetrated cell. In the present case, the general aspect of infection shows a close resemblance of the rhizomorph to a certain phanerogamic parasite, namely *Cuscuta*. Just as the stem of *Cuscuta* in contact with the host develops the haustoria, the rhizomorph strand creeping over the surface of the tuber gives off at intervals the infection branches. The latter penetrate into the cortical tissue of the host, pressing and partly dissolving it, and after arriving at the second layer of cells they give rise to the separate hyphae invading the neighbouring cells (Fig. 17).

Before producing the infection branch, the mother-strand sends out

1. The body in the aerial organ is safranin red in living materials.

from its surface, as the means of fixation, the thick-walled hair-like hyphae into the outermost cork-cells of the host. These hyphae are precisely comparable in function to the "cushion-cells" of *Cuscuta* (PEIRCE, '93) or root-hairs developing round the embryonal haustoria of some phanerogamic hemiparasites. Then, under this place the inner cortical mycelia of the strand multiply themselves, and upheaving and mechanically destroying the overlying thick-walled brownish cortical tissue, grow out to the exterior as an infection branch (Fig. 73). Hence, it is endogenous in origin like the ordinary branch of the strand (DE BABY, '84, p. 28) and also like the haustorium of *Cuscuta*.

## 2. LOCALISATION OF THE MYCORRHIZAL CELLS.

The filamentous hyphae arising from the infection branch of the rhizomorph strand harbour first in those cells of the second layer which lie immediately before the branch, and form in the cell cavity an entangled hyphal mass. The branches of hyphae then invade lateral neighbouring cells and thus the mycorrhizal cells are gradually increased in tangential direction throughout the second layer. Further, the hyphae reach the outermost cells of the third layer. The latter cells are consequently enlarged and become easily distinguishable by their size from the upper or lower cells.

Thus in *Gastrodia* the fungus infects the limited layers of the peripheral cells, *i.e.* the lower half of the second layer and outermost cells of the third layer. Such a local distribution of the mycorrhizal cells is hitherto known only, among the Orchidaceous mycorrhizas, in *Neottia* (MAGNUS, '00) and *Lecanorchis* (JANSE, '97), in which two or three layers of the cortical cells are typically infected, though in other orchids nearly all cortical cells entertain the fungus.

While the distribution of the mycorrhizal cells is thus limited in radial direction, it shows also more or less limitation in tangential direction; the endophyte is found only to a certain extent around the infected spot on the tuber (Fig. 14).

The extension of the mycorrhizal cells can be easily recognized by the



naked eye; the surface of the tuber becomes coarse in texture, and the cortical tissue so far traversed by the endophyte can be stripped off as a thick, somewhat hard coating from the underlying succulent tissue (Fig. 14).

In the strict sense of the word, we must use here the term "stem-mycorrhiza." The mycorrhiza formation in the stem was reported by MacDougal ('99) in several symbiotic saprophytes, in which the endophyte is found typically in the root. With rootless *Gastrodia* the encroachment of the fungus in the underground stem is perhaps a necessary process in accomplishing symbiosis.

#### IV. The Fungus.

##### 1. THE RHIZOMORPH AND ITS DEVELOPMENT IN THE FIELD.

The rhizomorph under consideration is in fact of very wide occurrence, and no case has ever been observed by me where it was entirely absent where *Gastrodia* vegetates. So in the vicinity of our College its ramifying strands are found creeping over the bark of the root, especially close to the old trunk, of *Quercus serrata* and *Q. glandulifera*, equally well on the living as on the dead stock (Fig. 4). There were also found the less branched but thicker strands traversing through the soil of the wood consisting chiefly of these trees. However, the root of the young stocks of the aforesaid trees and any other tree found in the same grove permits no special development of the strand. Again, an examination of the old oak planted along the roadside in the campus of our College has failed to find the rhizomorph attached to it. Although more or less vigorous development of it may be observed in the humus soil of woods and on the root of some other trees, yet so far my observations go, it seems to develop preferably on the root of oaks or in their surrounding medium.

The association of the rhizomorph and the said trees appears to show that the former is a form of the mycorrhizal fungus of the latter, becoming a symbiont of both the tree and the orchid as the case found by MacDougal ('99) in the *Aplectrum*-mycorrhiza. However, a careful examination of

fine rootlets indicates otherwise; the rhizomorph strand shows no connection with the rootlets, attaching only to the old root close to the trunk. In my opinion, the rhizomorph is nourished in saprophytic manner at the cost of the decaying bark of the root. The rootlets or young roots are unable to supply the rhizomorph with organic substances to be derived from the bark. Therefore, it is beyond doubt that the occurrence of *Gastrodia* mostly under old oaks must be ascribed to the predominant occurrence of its component at this place.

## 2. STRUCTURE OF THE RHIZOMORPH.

In maintaining that the rhizomorph is a mycorrhizal fungus, two important points must be definitely determined: the one is the identification of the endophyte to the rhizomorph and the other is the systematic position of the fungus to which the rhizomorph belongs. Leaving the detailed account relating to the former point for later sections, I shall in this place describe the structure of the rhizomorph to make out its systematic position clearly.

Several forms of the rhizomorph are hitherto known in higher fungi (DE BABY, '84, p. 23). Most of them accompany always the fruit body, so that their systematic position has been easily determined. However, the most familiar rhizomorph of *Armillaria mellea* Vahl. occurs usually without connection with the fruit body, and it has long been known as the sterile form of a fungus under the name of *Rhizomorpha fragilis* Roth., having two forms, *R. subterranea* and *R. subcorticalis*. It was R. HARTIG who first succeeded to find its genetic connection with *Armillaria mellea*, and after the investigation of DE BARY and BREFELD it becomes now evident that *R. fragilis* does not produce any other form of the fruit body than that of *Armillaria mellea* and that the rhizomorph of other fungi is quite different in structure from that of this mushroom.

The rhizomorph which I am now going to describe may be at once identified as *Rhizomorpha subterranea*. It forms a cylindrical, compact, smooth, black strand, usually 1-1.5 mm. in thickness (Fig. 3). Its peripheral portion, the so-called cortex, consists of compact, pseudoparen-

chymatous, brownish mycelium with a comparatively thick wall. The inner layer of the cortex is composed of the bundle of large but thin-walled mycelia with numerous septa. The inner cavity of the strand is traversed by a loose bundle of very fine longitudinal hyphae rich in plasmic contents (DE BARY, '84, Fig. 12), which correspond to the "secondary pith" of BREFELD ('77). On the outer surface of the strand are developed hair-like hyphae from the cortical mycelium, which afterwards fuse together into a gelatinous mass coating the strand.

These characters strictly agree with those of *R. subterranea*, distinguishing our rhizomorph from any other black one, for instance, of *Polyporus vaporarius* (SCHORSTEIN, '07, p. 46). The identification to *R. subterranea* is further enhanced by the fact that the fruit body of *Armillaria mellea* occurs frequently in the oak wood. I found it in June on the dead stump of *Quercus glandulifera*. The host had undergone already a great decomposition, being traversed by white mycelia. The ramified strands of the rhizomorph were not found over this substratum, but a few strands spreading in the soil were found in connection with it. From the colour, the general form, and the presence of the ring on the stem, this mushroom can be identified without hesitation as *Armillaria mellea* (Fig. 5). In the wood where *Gastrodia* vegetates this mushroom, inspite of vigorous development of the rhizomorph, is not of common occurrence. This is perhaps due to the fact that the mushroom preferably develops on the dead stump of the tree, which is in fact not found commonly in the wood I observed, while the rhizomorph strands can develop on the living stock of the same tree. As BREFELD already remarked, *R. subterranea* is the "Ausläufer," being incapable to nourish itself in the soil. The nutrient substances must be supplied by *R. subcorticalis* which develops on the bark of the living stock, or on the dead stump of the oak, and it seems probable that sufficient food-substances are liberated on the dead stump only, whereby the fruit body of the fungus is produced.

It may be noted that *Armillaria mellea* is familiarly known in other localities near Tokyo as one of the edible mushrooms. It is found there chiefly on *Quercus glandulifera* but often even on the dead stumps of seve-

ral other trees. The common occurrence of this mushroom in the vicinity of Tokyo would afford good evidence for the identification of the widely distributed rhizomorph to the mycelial strand of that fungus.

It has fortunately been possible through the courtesy of Prof. S. Goto to observe in the courtyard of his residence in Tokyo the habits of *Gastrodia*, proving an excellent demonstration of its relation to the fungus. He kindly told me that the yard had till seven years previous been an oak grove; *Armillaria mellea* has developed annually on the clean ground within a few feet from an isolately standing chestnut-tree and closely to its trunk, just as at a place of the same yard, where several garden trees and shrubs were planted; and the occurrence of *Gastrodia* has never been observed till the year before last. For the first time at the end of May of the last year, he was struck with the quite unexpected appearance of a certain number of inflorescence-axes of *Gastrodia* at just the same place of the yard where it was customary to collect the mushroom. Through his kindness I was able to ascertain the presence of *Rhizomorpha subterranea*, though not so abundant as may be seen in the humus soil of the oak grove. This indicates most clearly the association of *Armillaria mellea* and *Gastrodia* by means of the rhizomorph strand. The development of the mushroom at such an unexpected place is perhaps due to the fact that the stumps of the trees cut down, which had formerly composed the grove, were partly left underground and are now undergoing decomposition. Under this condition the fungus originally present in the form of the rhizomorph has become promoted in development, *i.e.* to give rise to the fruit body as well as the increased number of strands, notwithstanding an unfavourable appearance of the substratum at present for the development of the fungus.

## V. Differentiation of the Hyphae in the Host-Cell.

Broadly speaking, the hyphae of the endophyte do not essentially differ in structure from those composing the rhizomorph strand lying outside the tuber. As already described, the strand consists of several



forms of hyphae, of which the three essential forms occur in the endophyte in regular arrangement. According to the form of the hyphae, we may now distinguish the mycorrhizal cells into three regions:

First region (Fig. 17f). The outer two or three layers of the mycorrhizal cells contain the densely entangled and coiled hyphae. They are thick-walled, very seldom septate, and rarely branched. The peripheral filaments of the hyphal clump are slender, thin-walled, and rich in granular contents, showing the young stage of development. From the dimension and general structure they may be identified to the hair-like hyphal branches, which, as already referred to, become in *Rhizomorpha subterranea* a gelatinous coating of the old strand and in *R. subcorticalis*, particularly in its parasitic form, ramify separately in the substratum as an absorbing organ. We see that in the feature of development and in function they appear to resemble more closely the corresponding hyphae of *R. subcorticalis*.

In general appearance the hyphal clump seems to correspond to the similar clump found in the "fungus host-cells" known in most endotrophic mycorrhizas (Fig. 35). In *Neottia* MAGNUS ('00) reported the differentiation of these hyphae into the "Ringhyphen" which are thick-walled, almost empty of contents, and lying in the periphery of the clump, and the "Haustorienhyphen," which are thin-walled, slender, rich in plasmic contents, and occupying the central portion. Morphologically, we may also distinguish two similar forms in *Gastrodia*, their relative position being, however, reciprocal. As to the physiological significance of these different hyphae I cannot find evidence confirming MAGNUS' view ('00, p. 215). Probably the slender peripheral hyphae are simply a form younger than the central thick-walled ones.

Second region (Fig. 17s). It consists usually of a single layer of mycorrhizal cells beneath the former, which contain a little broader hyphae with a few septa and branches. The wall is always thinner than that of the former hyphae. Occupying the whole cell cavity as a dense hyphal mass, they appear very often pseudo-parenchymatous. Typically they run parallel and give origin to the hyphae of the first region. In these res-

pects they may correspond more or less to the inner cortical hyphae of the strand, or BREFFELD's "primary pith," though they are usually much smaller and variable in diameter.

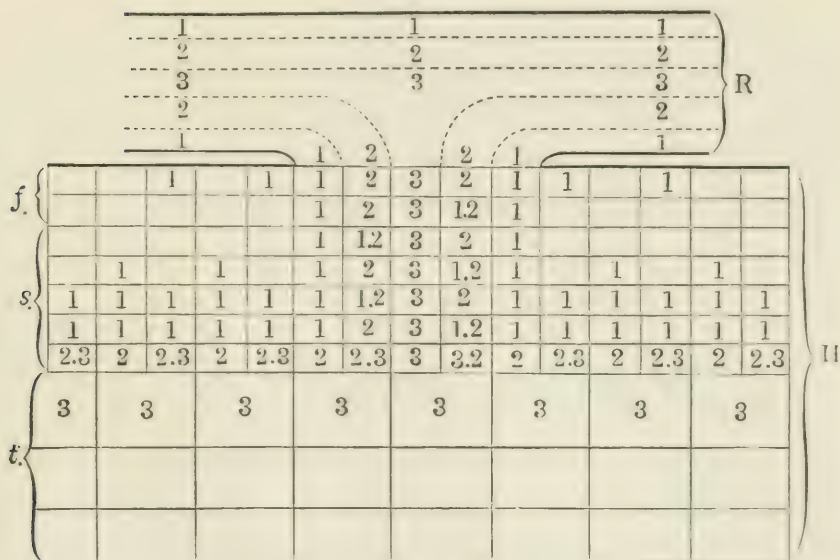
In the inner layer of the first region there are often found hyphae forming a clump, which are thin-walled and share the same fate as those in the second region, expressing the transitional form between the hyphae of the first and second regions.

Third region (Fig. 17*t*). In the innermost mycorrhizal cells we find fine slender hyphae, sometimes deeply stainable. The number of the hyphae entering each cell is very limited. They originate from the hyphae of the second region through a single pit on the limiting wall of each cell, and, without forming convolutions, radiate into the dense protoplast. The structure of the hyphae exactly coincides with that of the hyphae composing the secondary pith of the rhizomorph strand (Figs. 20, 28).

The infection branch mainly agrees in structure with the strand lying outside the host. It originates, as already explained, from the inner cortical layer of the mother-strand. It is easy, therefore, to see the continuation of the hyphae of the secondary pith, the more or less modified form of the cortical hyphae, and the outermost hair-like hyphae with the corresponding ones of the mother-strand. So that, the relationship of the different hyphae in the endophyte, the infection branch, and the ordinary strand, and their distribution may be represented as in the following diagram (Text-fig. 1).

When, as we have seen, the rhizomorph strand penetrates into a living tissue and develops as parasitic *Rhizomorpha subcorticalis*, the outer brownish cortical tissue is suppressed in development, while the hair-like hyphae are on the other hand promoted in growth. In this respect the symbiotic development of the fungus shows a close affinity to its parasitic development.

The difference of structure of the hyphae outside and inside the host was noted by several investigators in other endotrophic mycorrhizas (MAC-DOUGAL, '99, p. 41): in *Neottia*, according to MAGNUS ('00, p. 210), the hyphae creeping over the surface of the root have a few septa, and are



Text-fig. 1. Diagrammatic figure showing the arrangement of different hyphae in the rhizomorph strand and tuber. *R*, rhizomorph strand; *H*, tuber; 1, hair-like branch; 2, cortex; 3, secondary pith; *f*, *s*, *t*, first, second, and third layers of tissue.

broader and more thick-walled than the endophytic ones; and SHIBATA ('02, p. 655) reported in *Psilotum* the presence of septa in the hyphae outside the host, or inside its outer cortical cells, and their absence in the typical form of the endophyte. In the endophyte of *Gastrodia* the lack of hyphae with so many septa as seen in the normal strand might also show that the symbiotic form of the fungus undergoes more or less modification in hyphal structure.

The genetic relationship between the different hyphae of the endophyte is quite similar to that found between the corresponding hyphae of the rhizomorph strand. In the growing point of the usual strand we observe that the cortical hyphae make their appearance first, and the hyphae of the secondary pith and the hair-like hyphae are produced from them as internal and external branches respectively (DE BARY, '84). So also with the endophyte, the hyphae of the second region, which is, as already stated, comparable to the cortical hyphae of the strand, appear first and then send out branch hyphae in lateral direction, the hair-like branches on the

upper (first region) and slender hyphae on the lower side (third region). The further spread of the hyphae in the first region from cell to cell may be effected by their own branches, but the hyphae in each cell of the third region originate invariably from those of the second region through the dividing wall between the two regions, so that the lateral connection of the hyphae between the cells of the third region is in no case observed.

## VI. Cytology of the Mycorrhizal Cells.

### 1. ACTION OF THE PENETRATING STRAND.

The infection of the endophyte by means of a thick strand requires, unlike the infection by means of single separate hyphae as seen in most endotrophic mycorrhiza, a wide space for its penetration. The space needed is chiefly produced by breaking down a certain number of cells through mechanical and chemical action of the attacking hyphae. At the first stage of this process the cavity of the outermost cork-cells is entirely occupied by the hyphal clump. After destroying these cells the hyphae attack the underlying living cells and, dissolving partially or completely the dividing wall, give rise to a lysigenic space for the advance of the growing infection strand. The healthy cells surrounding this space contain now the same hyphae as in the first region already described. We see here that the fungus is capable to dissolve suberised as well as cellulose wall (Fig. 73).

A somewhat similar process has already been known in the parasitic rhizomorph, where its strand attacks any living tissue (Fig. 74). In this case, however, so far as observed in *Gastrodia-tuber*, the host-cells surrounding the strand are much compressed, and to a certain extent show brownish discolouration, expressing the restrain from their normal function. While thus the parasitic strand causes an apparent direct or indirect injury to the cells adjoining it, the symbiotic one does not at the outset injure the corresponding cells. Thus, except these slight differences, the infection branch of the symbiotic strand agrees in the main points of its behaviour



to the parasitic strand. Further, it may be stated that the action of the infection branch on the host is quite similar to that of the haustoria of *Cuscuta* and several phanerogamic root-parasites (Orobanchaceae, Rhinanthaceae, Santalaceae, etc.).

In certain layers of cells below the penetrating strand more or less increase of the amount of cytoplasm and the size of nuclei is observed (Fig. 73), while no such change occurs in the corresponding cells near the parasitic strand (see Fig. 74).

## 2. ACTION OF THE ENDOPHYTE ON ITS HOST-CELLS.

As mycorrhiza is formed equally well in the old tubercle as in the young one (Figs. 9-14), there is almost no doubt that the symbiotic development of the fungus is independent of the age of the intruding host cells. In reality the infection takes place in the permanent parenchymatous cells at a definite region. Restoration of activity is then observed in these cells, which cause several modifications in their internal structure. However, they are not capable of further division.

*a. Size.* No abnormal formation of tissue is observed in the infected tuber or its parts. Only it may be mentioned that the infected cells of the third region increase considerably their dimensions, becoming especially extended in radial direction. This begins to take place prior to the infection of the hyphae, attended by changes in their living contents. As already mentioned, these cells have originally the largest dimension, which becomes now more marked. On this point they seem to correspond to the specialised mycorrhizal cells in *Lecanorchis* (JANSE, '97), *Disporum* (JANSE, '97), and *Neottia* (MAGNUS, '00), all possessing a considerable size.

*b. Wall.* The wall of the parenchymatous cells, though rather thin, is pitted. The pits are usually round or oval, but sometimes irregular. The pitted wall is typically of cellulose nature, but, when infected, its chemical and physical qualities are more or less modified in different ways in different regions. In the third region the wall becomes much thickened making the pits more prominent (Fig. 17), while the chemical nature

remains unchanged. In the second region the thickening of the wall does not take place; on the other hand, the dividing wall between the two cells becomes thinner than before, and it is in greater parts resorbed by the perforating hyphae, the remaining portion showing still cellulose reaction.

Most remarkable change is observed in the first region. Lignification takes place during the thickening of the wall, not uniformly throughout the whole surface of the wall, but more prominently round the points perforated by the hyphae (Fig. 17 f).

In some cells we find a protuberance of the wall in the form of a long papilla projecting into the cell cavity. It is usually unbranched and stands isolated (Figs. 23, 28, 34), but sometimes occurs aggregated (Figs. 20, 36) and is often branched. It is passed through its central canal by the hyphae from the adjoining cell and forms a tubular sheath on them. The formation of the papilla takes place without exception in the third region wherever the wall is perforated by the hyphae, but this is not necessarily so in the first region, while it is absolutely omitted in the cells of the second region.

A similar structure has been found in other endotrophic mycorrhizas, for instance, in *Botrychium*, *Lycopodium* (LANG, '99), *Coffea* (JANSE, '97), *Lecanorchis* (JANSE, '97), *Calypogeia* (NEMEC, '04), and *Neottia* (MAGNUS, '00). Most of the authors regard the formation of the papilla as a device for protection against the invasion of the hyphae. The same interpretation may also be applied to the tubular sheath frequently formed by the host-cell round the haustoria of parasitic fungi (SMITH, '00). In *Gastrodia* the papilla seems to render the infection of the hyphae somewhat difficult, as shown by some papillae found as blind sheaths over the apical portion of the growing hyphal filaments. But this protective arrangement is practically less effective, since most of the papillae are actually perforated by the hyphae.

As noted above, papillae do not occur invariably at all points of the wall perforated by the hyphae. This seems to show that the formation of the papillae may be connected with a certain condition of the host-cell; the latter sometimes allows an easy entry of the hyphae and

sometimes more or less resists their penetration by forming the papillae. To determine whether the papilla is formed as a regulation of the fungal infection or not, further investigation is required.

The papilla, or tubular sheath, whether formed on the lignified or unligified wall, gives in all cases most apparent lignin reaction. When it occurs on the cellulose wall, it has its lignified basal portion always sharply delimited from the unligified wall (Figs. 20, 23, 28, 34). Thus, in its chemical nature, the papilla in *Gastrodia* does not agree with that in others. The same structure described by JANSE and MAGNUS is made of cellulose. SMITH ('00) also noted the similar structure developed round the haustoria of the Erysipheae to be of a cellulose nature. The lignification of the cell wall due to the attack of fungi is not, so far as I know, a universal phenomenon or perhaps is an unrecorded fact, and this peculiar case of response of the host-cell to the action of fungi seems to deserve special attention.

It is worthy of mention that the hyphae developed in the host-cells with lignified wall, i.e. mycorrhizal cells of the first region, give also the lignin reaction, most prominently in thick-walled hyphae. Thus they are coloured reddish violet with phloroglucin and hydrochloric acid, intense yellow with aniline chloride, green with  $\alpha$  naphthol, etc. This is certainly the most remarkable point of study, since the occurrence of lignin in fungi is still a disputed matter. NIGGL ('81), HARZ ('86), and SCHELLENBERG ('96) have detected lignin in a certain species of fungi, but FORSELL ('86) and LINSBAUER ('99) have failed to get positive results. In my present case the occurrence of the lignin substance on the wall of the mycelium is, to judge by the colouration, quite undeniable. The colouration is not uniform throughout the hyphae, some portions being coloured more intensely than others. Generally, it is clearly represented in the central portion of the hyphal clump, while the thin-walled young hyphae occupying its peripheral portion show no such reaction. Most remarkably, the pronounced reaction is observed on the hyphal filament that comes through the tubular sheath, the reaction decreasing gradually towards the portion farther from the sheath. This

latter fact tends to show that the lignin reaction of the hyphae is attributable to a thin coating of the lignified sheath over the surface of the filament, in other words, the reaction in question indicates the extension of the lignified wall of the host along the hyphae, pointing out in consequence that the lignin substance is derived not from the fungus itself, but from the host. Owing to the thinness of the wall of the hyphae, we are, however, unable to distinguish the inner true membrane of the hyphae and the outer lignified lamella. The wall always appears under the microscope homogeneously coloured by lignin reagents through both inner and outer layers, giving evidence in support of the view that the lignin substance is introduced uniformly into the wall.

It must be noted that the lignification of the hyphal wall is seen only in the cells of the first region, that is, in cells with lignified wall, while the hyphae of the second and third regions as well as any hyphal filament composing the rhizomorph strand show in no case such a process. This appears to show that the lignification in the fungus is in a certain way correlated with the same process in the host-cells. However, it must be remembered that the same relation is not maintained in the third region. Though the lignified tubular sheath is formed here as in the first region, the hyphae passing through it do not show the lignin reaction at all. This would seem to keep us from generalising that the lignification of the hyphae is due to the extension of the sheath over their surface.

As to what part lignin does play in the organization of mycorrhizal cells we cannot give a satisfactory interpretation. It requires further research to decide whether it is derived as a protection of the host against the injurious action exercised by the fungus endowed with parasitic properties, or whether it acts favourably on the fungus for its survival after the death of the host, assuming that the host-cell is in general more durable when the wall is lignified. Further, we cannot yet assert that the lignification of the tubular sheath is a more favourable process for protection against the attack of the fungal hyphae than when it is made up of cellulose.



*c. Cytoplasm.* The action of the endophyte upon the cytoplasm of the host-cell is already visible prior to the arrival of the phyphae. All the mycorrhizal cell, having attained to the permanent state like other parenchymatous cells of the tuber, contain originally a thin plasmic membrane along the wall encasing a large quantity of cell sap (Fig. 26), but when the hyphae approach them, the plasmic contents become much increased and more granular. Further, after entertaining the endophyte, there are seen several additional alterations, different according to the different regions.

In the first region the infected hyphae form immediately a small clump in the centre of the plasmic mass, and accompanying its subsequent enlargement the surrounding cytoplasm is expanded and stretched out into a membranaceous envelope of the clump. At later stages, when the clump grows to fill up nearly the cell cavity, the cytoplasm appears decreased in amount and at last disappears entirely. Whether it is due to the consuming action of the endophyte or to its self-disorganization remains yet undecided.

In the cell of the second region the dense plasmic mass filling up the cavity and containing only a few small vacuoles is rapidly resorbed by the fungus soon after its infection, and its decrease in amount and the increase of the hyphae go on at the same pace. In the end the protoplast is entirely consumed by the fungus when the cell cavity is occupied by an entangled mass of the hyphae (Fig. 31). The consuming action is here very active and truly no symbiotic association is indicated at all.

In the third region the relation between the hyphae and the cytoplasm is exhibited otherwise. The infection of the hyphae induces a dense granular appearance of the cytoplasm formerly reticulated, and at the same time a further increase of its amount. The hyphae are then imbedded in the cytoplasm and make no noteworthy development.

Thus the action of the endophyte upon the cytoplasm of the inhabiting cells is expressed in different ways; in the second region the cytoplasm is rapidly attacked and in the third region the endophyte

favours the cytoplasm for the increase in amount, while in the first region the reciprocal action is in an intermediate state or nearly neutralised.

*d. Nucleus.* The nucleus of the mycorrhizal cells undergoes also remarkable alterations. In the intact cells in each region the nuclei, being all at resting stage, are spherical and comparatively small, and small chromatin granules are densely arranged on the network (Figs. 58, 61, 64, 65). As already observed by SHIBATA in *Alnus* (02, p. 668), MAGNUS in *Neottia* ('00, p. 232), and previous authors (DANGEARD, '97), when the endophyte approaches these cells, the nuclei increase in size and cause the enlargement of chromatin granules, these changes going on parallel to those of the cytoplasm (Figs. 59, 62, 67). Such general changes occurring before the arrival of the endophyte are followed after infection by further modifications in different processes according to the different regions. So in the first region we see an irregular deformation of the nucleus, assuming sometimes amoeboid and sometimes stretched form, and resulting in the increase of its surface (Fig. 60). The decrease of space in the cell cavity due to the massive development of the hyphal mass seems to have more or less influence on the deformation of the nucleus; rarely it is found packed in the hyphal mass, producing several constrictions, or it is compressed and flattened between the mass and the cell wall, but more generally it is stretched out at the median portion into unequal halves, which, though seldom, may result in fragmentation into two nuclei lying farther from each other in the periphery of the hyphal mass (Fig. 35). Accompanying the vigorous development of the hyphae there is seen, together with the disappearance of the cytoplasm, an atrophy of the nucleus, being expressed by the decrease of its size, by becoming less stainable, and by final disappearance.

No noteworthy change is observed after infection in the nucleus of the second region. The vigorous consuming action of the endophyte makes hyperchromatic nuclei soon disappear together with the cytoplasm, allowing perhaps no time for them to undergo several further changes.

Worthy of special mention is the modification of nuclear structure

in the third region. The nucleus, originally already slightly larger than that in other regions or other portions of the tuber, begins now to enlarge, attended by a remarkable increase of chromatin and by a most conspicuous deformation. The chief deformation observed at the first stage is expressed by the occurrence of several constrictions (Fig. 68). Each constricted portion assumes generally oval form with a smooth outline; however, such an amoeboid outline as observed in the digestive cells (in *Neottia* by MAGNUS and *Psilotum* by SHIBATA) has never been ascertained.

In advanced stages it frequently occurs that the constricted portions are pulled apart radially and the nucleus gives a stellate form (Fig. 69). Although such a form appears to exhibit the process of fragmentation as found in most cases of mycorrhiza (*Ophrys*, DANGEARD, '97; *Peranium*, MACDOUGAL, '99; *Lecanorchis*, JANSE, '97; *Orchis* and *Listera*, MAGNUS, '00; *Podocarpus*, SHIBATA, '02; *Platanthera* and *Epidendrum*, BURGEFF, '09; etc.), yet in no case have I been able to make out conclusively the breaking down of the portion stretched out and the consequent fragmentation of the nucleus. It may be remarked that, in the preparation of microtome sections, spherical nuclei are in view, confounding with the real fragmentation (Figs. 27, 30). This is due quite certainly to seeing a section of a stellate nucleus through its peripheral portion.

The arrangement of chromatin is highly characteristic in the nucleus having undergone such deformation. In the stretched portion it ranges in many longitudinal threads as seen in the spireme stage of dividing nuclei, and all the threads unite into a median bundle leaving between it and the nuclear membrane a wide clear space. Entering the constricted portions the threads diverge and dissolve into a network (Figs. 70-72).

Previous to the constriction of the nucleus, the nucleolus is first elongated and then fragmented into numerous smaller ones which enter the constricted portions, two or three into each. Thus each portion appears in morphological structure like an individual nucleus, and we have to assign to such deformed nuclei similar physiological significance as possessed by the fragmented nuclei.

After reaching the critical point of deformation the nucleus comes gradually to resume its original state, contraction of the stretched portion and decrease of constrictions as well as the chromatin mass proceeding step by step. Besides, we often see that the nucleus before restoration to the original form shows degeneration, becoming densely granular and deeply stainable, and showing an irregular outline (Fig. 30).

The position of the nucleus in the cell cavity seems to show a tendency to be excentric. In most cases it lies rather near the side from which the hyphae come; its position near the opposite side has never been observed, though it takes frequently a central position.

The significance of the above features involved in the nucleus of the mycorrhizal cells will be considered later in connection with the organization of the mycorrhiza.

### 3. PARASITIC ACTION OF THE RHIZOMORPH.

When the strand of *Rhizomorpha subterranea*, while traversing the humus soil, has occasion to meet with some living roots of trees, it often develops in the living tissue to enjoy parasitic life as *R. subcorticalis*. Attacking the living tissue of *Gastrodia*, the rhizomorph, instead of destroying the host, behaves as a rule favourable for its existence. Such association is not, however, constant. The fungus, being parasitic, though commonly saprophytic, may exert under certain circumstances an injurious action upon *Gastrodia*. In this case the strand penetrates into the tissue of the tuber in the form of *R. subcorticalis*, ramifying its branches in indefinite directions. The internal relation between the fungus and the host-cell is quite different from that of symbiotic association: recovering of the activity of the plasmic contents does not take place; the strand growing through the lysigenic space among the tissue causes compression of the surrounding cells and sends out into them a few hair-like hyphae from the cortical tissue; the cell sap contains a brownish matter; and the nucleus causes chromatophily (Fig. 74). All these facts express the impossibility of the normal function of the attacked cells, that is, an apparent death. As the development of the fungus



accords quite well with that of *R. subcorticalis* attacking a living tree, which was described in detail by HARTIG ('74), we are justified to assign the above features of the host-cells to the parasitic action of the fungus.

The development of the parasitic rhizomorph is usually observed in tubers that have gone to the last stage of activity, which arrives regularly at the end of each vegetative period. Yet, as a most remarkable fact, it may be seen even in an apparently vigorous tuber. Perhaps this dual relation between two organisms is presented by the difference of the condition of the organism attacked.

## VII. Organization of the Mycorrhiza.

1. The cytological studies of the mycorrhizal cells reveal that there exists an antagonistic relation between the fungus and the inhabiting cells. This relation is exhibited most clearly in the second and third regions, where the destroying action of one symbiont on the other goes on quite reciprocally. However, in the first region, it is less apparent, showing perhaps a balanced state of mutualism. In the latter region neither the fungal hyphae effect an apparent injury on the protoplast of the host, nor can we find an unfavourable action of the host on the infecting hyphae. It is only seen that the increase of the hyphal filaments gives mechanical hindrance to the normal function of the protoplast; but this taking place very slowly, the two symbionts may exist intact for a long time, though the protoplast becomes ultimately the victim of the fungus. It may be considered that the precipitation of the lignin substance on the surface of the hyphae may interfere with the reciprocal action between the hyphae and the protoplast, or at least it makes this action highly difficult.

The mode of development of the fungus in the second region is perhaps unique in the mycorrhizas we know at present. The hyphae exert a highly destroying action on the increased protoplasm: it is rapidly resorbed soon after the infection of the hyphae. A similar action is also observed on the cell wall: the hyphae dissolve more or less the penetrating wall. It must be a remarkable fact that the destruction is nearly

completed before the mycorrhiza formation is not yet wholly accomplished. The cell cavity is then filled up with irregularly curved, thinner-walled hyphae rich in plasmic contents. After full development these hyphae soon collapse: the contents condense into deeply staining strings (Fig. 32), the hyphae become much swollen, the strings then disappear (Fig. 33), and the wall, losing a definite structure, is found scattered in the cavity of the host-cell as a structureless remnant (Fig. 34). At the later stage of this process there appear fine slender filaments corresponding in structure to the hyphae of the secondary pith of the rhizomorph strand (Fig. 33). These filaments are in direct connection with the hyphae of the third and partly of the first regions.

The collapse of the hyphae presents quite a similar phase to that observed in the "digestive cells" of the usual endotrophic mycorrhiza. The process, however, is quite different from the latter case, though the physiological significance appears, in my opinion, to be the same, inasmuch as the decomposed substance of the hyphae may be utilised by the host. As we know, the change of the hyphae in the digestive cells is due to the digestive action of the protoplast of the host-cell, which can be seen from various deformations of the nuclei during that process. However, in the present case the protoplast has previously disappeared, or perhaps has been consumed or digested by the fungus. Therefore, unless the surrounding cells are concerned in the digestion, which, however, is very improbable, the collapse must be undoubtedly due to a degenerating process in the hyphae themselves.

The consumption of the protoplast by the fungus in the second region shows quite evidently the parasitic property of the endophyte. Reciprocal relation between the two symbionts is found to occur in the third region. There is no indication of a favourable contrivance for the existence of the fungus; on the other hand, we can point out several evidences supporting the view that the host-cell receives benefit from the fungus. In fact the mycorrhizal cells of this region are the metabolic centre of the higher symbiont; there is an abundant accumulation of substances derived from the fungus.

Associated with this we see the most complex organization taking place in this region. The increase of cytoplasm reaches the highest point, as soon as the hyphae reach the overlying cell of the second region, and at the same time the previously hypertrophied and hyperchromatic nucleus becomes deformed, chiefly by producing constrictions. Starch grains are as yet present as much as other normal cells of the region. The infection of the hyphae causes immediate disappearance of starch, and the typical deformation of the nucleus ensues. The cytoplasm becomes more dense and its granular consistence more prominent, especially round the nucleus. Comparatively small vacuoles occur on the peripheral portion, but more numerous on the side opposite to that traversed by the hyphae. The excentric position of the nucleus towards the side the hyphae are entering is most probably an indication of the existence of a close relationship bearing on the activity of the nucleus and the infecting hyphae. The absence of vacuoles in the cytoplasm around the hyphae and the granular structure of the cytoplasm in that portion will also show quite beyond doubt that the metabolic action is taking place chiefly in this place.

That the third region is the centre of the metabolic activity of the mycorrhiza is evidenced by the appearance of secondary products in the cytoplasm after the infection by the fungus, which may be classified as follows:

(a) *Homogeneous Globules.*

This is a somewhat hyaline, spherical mass, light yellowish brown in alcohol specimens. Small, irregularly shaped, colourless spots are present in the matrix, which are evidently vacuoles. It takes up always several colouring matters; thus staining deep red with triple stain (Figs. 17, 22), green or violet green with fuchsin iodine green (Fig. 19), black with haematoxylin, red or reddish violet with a mixture of ruthenium red and methyl green. It is resistant to several acids, insoluble in caustic potash, coloured orange brown with potassium iodide-iodine, not blackened with osmic acid, and easily soluble in Eau de Javelle solution. MILLON'S reaction is negative.

The number of these globules occurring in one cell and their size vary considerably, the larger number ranging between five and seven, and the larger globules measuring from 0.07 to 0.085 mm. in diameter.

(b) *Vesicles.*

A spherical vesicle is found together with the globule, usually in the same cell. Within the distinct membrane are found granular contents, sometimes packed in compactly (Fig. 27) or sometimes scattered in the hyaline space (Fig. 29). The granules are light yellowish in alcohol specimens, becoming more intense by iodine. The vesicle containing the less number of granules takes on an appearance as may be confounded with a resting nucleus (as in conifers). In colour reaction the granules are somewhat different from the globular mass, being stained violet with triple stain, violet or reddish violet with fuchsin iodine green, not or only faintly coloured with haematoxylin, reddish with a mixture of ruthenium red and methyl green, etc. Eau de Javelle solution dissolves them easily. Towards the other reagents they show the same reaction as the globules. The number of vesicles occurring in one cell is usually less than that of globules, but the size is equal or greater, being 0.08-0.1 mm. in diameter. From the staining reaction it may be safely stated that the contents of the vesicle is a substance different from the globular substance.

The globule and vesicle are always packed compactly in the cytoplasm.

(c) *Small Bodies.*

Numerous small hyaline bodies occur in the vacuoles of the cytoplasm. Their form is extremely variable, mostly spherical and oval (Figs. 19, 22), but sometimes very irregular, leaving often clear space in the centre (Figs. 54, 56, 57). Staining property is different from the above two bodies: they stain pale violet brown with triple stain, reddish with fuchsin iodine green, not or very faintly coloured with haematoxylin, reddish with a mixture of ruthenium red and methyl green. They are more resistible to Eau de Javelle, but to other reagents they behave similarly as the former two. Their number is much increased in later stages (compare Figs. 27, 29).



Besides three different bodies mentioned, there are also found some bodies of combined characters. A globular mass showing by the staining reaction the same nature as the globules of the first kind takes on a fine granular consistence resembling the compact vesicle, or a small globular body appearing like one of the third kind has its central portion similarly stained as the typical globule, while its peripheral portion is stained as the typical small body (Fig. 19).

The adjoining table (Table I) will show the comparison in the staining reaction of these bodies, the mycorrhizal cells, and the fungus:

Table I.

Stain Object		Fuchsin iodine green	Flemming's triple Stain	Heidenhein's iron haema- toxylin	Methyl green & ruthenium red	Ruthenium red
Mycorrhizal cell	Cytoplasm	Red	Pale red or reddish violet	Unstained	Pale red	Pale red
	Chromatin	Green or violet	Bluish violet	Black	Red	Pale red
	Nucleolus	Red or violet	Red	Light black	Red	Red
	Lignified wall	Greenish blue	Dense red	Black	Green	Unstained
	Cellulose wall	Red	Violet	Unstained	Red	Red
	Tubular sheath	Greenish blue	Dense red	Black	Green	Unstained
Fungus	First region	Green	Red or violet	Light black	Green	Pale red
	Second region	Red or pale violet	Pale violet	Contents black	Red	Red
	Third region	Red	Blue or pale violet	Unstained	Red	Red
Fungus product	Globule	Green or blue violet	Dense red	Black	Greenish red	Intense red
	Vesicle	Reddish violet or violet	Violet	Light black	Red	Pale red
	Small body	Red	Pale violet	Light black	Red	Pale red
	Granular region round the hyphae	Red	Blue or pale violet	Unstained	Red	Pale red

During the activity of the cells of the third region it is observed that the relative number of these different bodies occurring in a single cell varies much at different periods. At first the globules and vesicles predominate, while the small bodies are exceedingly few in number, being scattered in the peripheral portion of the cytoplasm (Fig 27). At this period the position of these bodies is noticeable; the first two are central or excentric towards the second region, while the last body mostly lies on the opposite side.

At later stages the globules as well as the vesicles begin to disappear. In the former, as the first step of this process, the staining power is reduced and numerous vacuoles appear. Still later, the globule shows uneven outline, often shrunk into an irregular mass. The vesicle diminishes the granular contents, until it becomes quite empty, followed then by the shrinkage of the wall (Fig. 51). During these processes the small bodies increase in number and become distributed uniformly throughout the cytoplasm (Fig. 29). Lastly, perhaps at the end of activity of the cell, they gather altogether in one or two, generally central, vacuoles close to the nucleus, and are fused together into a mass or masses, giving more or less dense portions (Figs. 21, 30), while the globules and vesicles become quite invisible.

At this stage a noteworthy phase is observed in the protoplast. The cytoplasm diminishes considerably and assumes a coarse network structure, encasing many large or small vacuoles. The limiting plasmic layer between the vacuoles becomes at times membranaceous. Probably the apparent increase of the cytoplasm at previous stages has been due mainly to the accumulation of elaborated substances which are distinguished from the somewhat fibrous true cytoplasm by their being granular. These substances are now exhausted, whereby the cytoplasm is rendered more fibrous and vacuolate. The nucleus has reached the critical point of deformation during the appearance of the globule and vesicle, and during their diminution. Now, it contracts from the stretched form and diminishes its chromatin contents, assuming the structure which it had taken shortly before the infection of the hyphae. It is very plain that the increase of chromatin,

attended by the increase of surface at the given stage, bears a certain relationship with the highest activity in elaboration of food materials or other processes, as MAGNUS and SHIBATA have described and reviewed at full length. However, it must be remembered that the somewhat similar feature taken by the nucleus in the second region is not assigned to the same cause. It is very probable that the increase of chromatin and size of the latter nucleus expresses its being under similar condition as the nucleus of the cell infected by parasitic fungi, for instance, *Synchytrium* (KUSANO, '09, GUTTENBERG, '09). It may be also comparable to a degenerating phenomenon described by MAGNUS ('00, p. 251) in the nucleus of the fungus host-cells of *Neottia*.

Let us now turn upon the origin and real nature of the globule, vesicle, and small body. It is a matter of course that their occurrence may be assigned to the presence of the endophyte. The important points attached to this problem are their mode of derivation and their nutritive value for the higher symbiont. As regards the globule, I can safely state that the larger one shows no direct connection with the hyphal filament, but some small globules are found attached to it, showing the derivation from the fungus. At an early stage the hyphae are rich in contents, and, as a rule, take on light violet colour with the triple stain, intense red with fuchsin iodine green, red with a mixture of ruthenium and methyl green, but no colour with haematoxylin. Afterwards, some hyphae or their portions become heavily stained with safranin or haematoxylin, owing evidently to the presence of a special content (Figs. 24, 28). I have to compare such hyphae with the "Eiweisshyphen" known from some Orchidaceous mycorrhizas, and consequently their content with the protein substance. It is noticeable that this content is, by the staining character, in strict agreement with the globular substance. Frequently the end of the hyphal filament is followed by a row of small globules; otherwise they lie along the filament (Figs. 28, 45, 46). It appears as if the filament is fragmented into pieces, each then becoming spherical. Such an arrangement of the globules indicates that they are the secretion product of protein from the hyphae. This statement may be supported by the accumulation of

the protein substance at the end of the filament and budding of oval globules from its lateral side (Figs. 18, 24, 44, 46). Frequently it happens that the filament produces several nodules at intervals in which the stainable content is condensed, each nodule being connected in chain by a fine string (Fig 24). It seems to me that BURGEFF's view ('09, p. 120) of the protein hyphae as metamorphosed spores of the endophyte is based on such a phase of accumulation of the protein substance. While thus the small globule is produced undoubtedly by the secretion process going on in the hyphal filament, the evidence for the direct derivation of the larger globule from the hyphae is not apparent, since its relative position to the latter is quite otherwise. I am of opinion that it is formed by the fusion of small globules. The deformation of the globule, which frequently came under my observation, indicates its viscous consistence (Figs. 22, 28) and makes the fusion highly probable.

As to the protein substance forming the globule, it is probable that it originates in part from the protoplast of the degenerating hyphae of the second region. Shortly before degeneration the contents of the hyphae are condensed into a well-stained string running longitudinally through the cavity of the hyphae (Fig. 32). Its staining character is quite the same as the globular mass. At the moment when the hyphae undergo degeneration the string disappears entirely, most probably it is transmitted into the hyphae of the third region and is secreted out into the cytoplasm, with or without complex decomposition, in a form of globule. The large amount of the substance constituting the globule, however, shows the necessity of assuming an additional source, the latter being most certainly the rhizomorph strand lying outside the tuber.

The vesicle appears to correspond in structure to that generally occurring in many Orchidaceous or non-Orchidaceous mycorrhizas (GROOM, '95b; JANSE, '97; MACDOUGAL, '99; LANG, '99; SHIBATA, '02; GALLAUD, '05). In origin, however, it does not agree strictly with the latter. The larger vesicle, like a larger globule, shows no connection with the hyphae, but the smaller ones are truly produced as terminal swellings of the hyphal filament, or lateral budding, sometimes in club- or oval



shape, and indeed on the same filament that derives the small globules (Figs. 22, 44, 46, 47, 48). Near the hyphae are found isolate vesicles in similar dimensions (Fig. 43). These smaller vesicles, just as the larger one, are provided with a very distinct wall, originated without doubt from the mycelial wall. It is evident that the granular content originates from the hyphae, since we find the accumulation of the granular substance in the portion of the hyphae close to the vesicle (Figs. 47, 48). As to the origin of the larger vesicle, I cannot express a definite view. In no case have I been able to detect, in the many preparations I examined, its bodily connection with the hyphal filament or any sign of its being a swelling of the filament. It is highly improbable that it is produced by the fusion of smaller vesicles, as does the globule, since each vesicle has a distinct wall. The only probable interpretation about the occurrence of the larger vesicle is that the smaller vesicles may grow after detaching from the filament, taking the material from the surrounding cytoplasm, which has of course originated from the fungus.

These prominent inclusions of the cytoplasm cannot be taken in any way as the "Sporangioles" denoted by the old writers. The latter are of usual occurrence in mycorrhiza, in its digestive cells. As was first announced by FRANK ('91) and then confirmed by FIGDOR ('97), MAGNUS ('99), SHIBATA ('02), GALLAUD ('05), BERNARD ('09), BURGEFF ('09), and others, they are, however, nothing else than a lump formed by the undigested wall of the hyphae. The presence of this lump is almost universal, according to BURGEFF's recapitulation, in the Orchidaceous mycorrhiza, with the only exception of *Lecanorchis*. In *Gastrodia* I can also confirm the digesting process in the cell of the third region, but the hyphae present are exceedingly less to leave a massive remnant of their wall as a lump.

Now we come to the origin of the small body. In connection with this we observe a certain alteration in structure of the hyphae, reminding us of the digestive process taken by the higher symbiont. After or perhaps during the formation of the globule and vesicle certain portions

of the hyphal filament are surrounded by a fine granular region which can be distinctly limited from the fibrous cytoplasm (Figs. 25, 28, 45-47, 49). The staining character is different from the latter, taking the stains quite similarly as the hyphae themselves, thus blue or light violet with the triple stain, while the surrounding cytoplasm takes more or less safranin. Potassium iodide-iodine stains somewhat yellowish, showing the negative reaction to glycogen. I cannot yet decide with precision whether the granules are the product of the hyphae or of the cytoplasm as zymogen. However, we would like to assume the content of the hyphae as their origin and to take them as the food materials to be utilised by the host directly or after entering the growing vesicle. Later, a clear space is developed between the hyphae and the granular region. The hyphae then become faint, empty, and homogeneous as if the content was exhausted. Next the granules are gradually resorbed in the cytoplasm. I am not able to trace step by step the subsequent stages, and I cannot express with accuracy the fate of the hyphae under such condition. Still the facts that the hyphae lose their definite structure, are fragmented, and form, more or less contracting, less stainable irregular masses or somewhat spherical bodies in the clear space in the granular region would sufficiently show the genetic connection of the small body with the hyphae undergoing the changes indicated. I take, therefore, the small body as the remnant of the hyphae. This view is strengthened by the fact that its increase in number goes *pari passu* with the disappearance of the hyphae.

The small body may also originate from the globule and vesicle. At the time the globules are disappearing one by one, there begin to appear, among irregular small bodies given above, similar but larger vacuolate masses taking the same stains as the former. The large dimensions, round form, and vacuolate nature point to these masses being the ground substance of the globule. In fact we have observed at the later stage of the dissolution of the globule that the peripheral portion loses the staining power owing to the diminution of the essential component and exhibits homogeneous but vacuolate nature. This ground substance remains behind after the complete exhaustion of the protein substance and, contract-

ing considerably, is thrown into a vacuole of the cytoplasm in a form indicated (Figs. 54, 56). Again, in the dissolution process of the vesicle we observe the disappearance of the granular content, but its hyaline wall remains unattacked. From compression of the surrounding cytoplasm, the empty vesicle begins to shrink (Figs. 51-53), and the wall is then thrown into the vacuole as an irregular mass but often in a stellate form (Fig. 56). It must be noted that the small bodies in vacuolate globular or stellate form do not appear while the globule and vesicle remain intact, thus making the genetic connection of the former with the latter highly probable.

Respecting the origin of the small body I can further add another fact. When the activity of the mycorrhizal cell is over, the hyphal filament secretes along its surface small less stainable globules, while the filament itself becomes faint in appearance (Fig. 22). The filament is also at once broken into pieces, each piece becoming an irregular mass (Fig. 50). The globules and the mass can by no means be distinguished from the small bodies already present.

Although the small body is thus derived in various ways, it is shown that in all the cases it has material connection with the hyphae. Judged by the resistant character towards several reagents, this body would consist essentially of cutinous substance originated from the hyphal wall (WESTER, '09). If there be partly other substances of different origin, it appears yet probable that they are all useless matter.

From what we have stated above, we may point out the physiological significance of these inclusions. The globule and vesicle are the secretion products of the fungus and are for the host essential nutritive elements. The small body is useless substance for the nutrition of the host, and, though its origin may be various, it may be conveniently included under the name of excreta, as ZACH ('08) so named the similar body found in *Alnus*.

The loosely fused mass of the excreta (Figs. 21, 30) gives an appearance quite similar to the "clump" found in the digestive cells of other mycorrhizas. The clump is usually surrounded by the cellulose membrane



secreted from the cytoplasm, or rarely, as in *Psilotum* (SHIBATA, '02, p. 659), by an amyloid substance. However, no such a substance is found in the present case; the mass occurs freely in the vacuole.

When the globule and vesicle disappear and the small bodies increase in number, the cytoplasm diminishes exceedingly and becomes highly vacuolate. This will show the end of the activity of the cell. It is at this stage that starch grains begin to reappear in the cytoplasm (GROOM, '05 b; MAGNUS, '00).

As regards the whole organization of mycorrhiza and the anatomical relation between the symbionts, *Gastrodia* may be compared with *Lecanorchis* which has been studied by JANSE ('97) and has been taken by BURGEFF ('09) as a special type ("Sporangiolenpilze") of the Orchidaceous mycorrhizas. According to JANSE, the root of this orchid is traversed on its surface by a mycelial strand. The branches of the hyphae penetrate into certain epidermal cells and give off permanent mycelia filling up a certain zone of the cortical cells. The cell immediately below this layer is infected by the separate hyphae. The cell is the largest, rich in plasma, its nucleus is enlarged and much fragmented. JANSE mentioned that the apex of the hyphal filament in this cell swells up and develops into the vesicle, containing refractive, spherical or polygonal bodies, coloured brownish with iodine. On these accounts we find a close resemblance of this cell layer with my third region—size of the cell, behaviour of the nucleus, amount of the cytoplasm, manner of the hyphal infection, and perhaps function of the mycelium. Further, the permanent mycelia may correspond to those of my first region. The only difference lies in the manner of penetration of the infecting mycelium; it is there caused by a bundle of a few, loosely arranged hyphae passing through the epidermal cell (see his Figs. 2-5, Pl. XIII), in *Gastrodia*, however, by a thick compact mycelial strand.

From these similarities which *Lecanorchis* and *Gastrodia* have presented, it may naturally be inferred that the vesicle in both plants might be of a similar nature, being the secretion product of the fungus. I am, therefore, against the views which admit this body in *Lecanorchis* to be a



structure analogous to the "Klumpen," or to be the degenerated "Arbuscules" (GALLAUD, '05) or the "Organe des Pilzes" (BURGEFF, '09).

GROOM ('95 b) mentioned a similar differentiation of mycorrhizal cells in *Thismia*. The innermost layer (in mediocortex) behaves similarly as the corresponding layer in *Lecanorchis*; the hyphae collapse after forming a terminal bladder which gives out a yellow liquid, containing numerous rod-like bodies exactly comparable to the yellow deposits in *Lecanorchis*. He considered it to be resistant excreta absolutely useless to the higher symbiont (p. 353). LANG ('99) described the vesicle in *Lycopodium*-prothallium, which shows in many respects the most close similarity to that of *Gastrodia*, but he did not express a definite view on its significance. CAMPBELL ('08) gave the similar structure in fern prothallia as being the conidium of the fungus. Thus there prevail very divergent views on the nature of vesicles from different mycorrhizas, and to ascertain whether they are analogous or homologous structures, we must await further comparative study.

2. Most of the endotrophic mycorrhizas have a mycelial connection of the endophyte with the surrounding medium (JANSE, '97; LANG, '99; MAGNUS, '00; SHIBATA, '02; BURGEFF, '09; etc.). The connecting hyphae are, however, so poorly developed, in contrast to the endophytic hyphae, that many authors are inclined to take them as the infecting hyphae, and to put the nutritive connection between the surrounding medium and the inner tissue of the host through the agency of these hyphae in question. LANG (p. 295), finding in *Lycopodium*-prothallium the hyphae passing out into the soil through the rhizoid from the interior, which is shown by the direction of growth opposite to that taken by the infecting hyphae, clings to the view that the connecting hyphae are the conveyer of the organic material from the soil to the host. BURGEFF's studies on orchids lend support to this view. At any rate, the anatomical data obtained from this form of mycorrhizas seem to be still inadequate to draw precise conclusions as to the real function of the hyphae outside the host. The case is, however, otherwise in *Gastrodia*. The main portion of the fungus develops outside the host, with which the endophyte

is connected by a thick mycelial strand. Such a mode of development of the symbiotic fungus shows no doubt an ectotrophic mycorrhiza, while on the other hand the internal relation between the two symbionts expresses the mycorrhiza to be a typical endotrophic form. In consequence the present instance of mycorrhiza must be regarded as a combination of endo- and ectotrophic forms.

As far as I know, such a peculiar case of mycorrhiza has not yet been thoroughly investigated. According to JANSE ('97, p. 121-123) the endophyte of *Coffea*, *Cotylanthra*, and *Lecanorchis* have connecting hyphae forming a loose bundle, similarly as in *Gastrodia*. But as a detailed account on the development of the fungus in the soil is not recorded, we cannot determine whether the nutritive relation in these cases is strictly the same as in *Gastrodia* or not.

3. MAGNUS thinks that the thick-walled hyphae remaining intact in the "fungus host-cells" are a resting form, which after the death of the host-cells survive till the next year to accomplish a new infection on the newly derived root of the host. In *Gastrodia* the hyphae of the first region of the mycorrhizal cells, having a similar structure, appear also to play a similar function. However, the infection of the fungus is whenever performed by the strand of *Rhizomorpha subterranea*, and there is no necessity of forming the resting hyphae in the endophyte for a subsequent infection. If there be any function, we should like to say, based on the habit of *Armillaria mellea*, that the hyphae under consideration hibernate after the disintegration of the host tissue and utilise in the next vegetative season the decomposed organic matters from the dead body of the host, as does *Rhizomorpha subcorticalis*, to nourish the strands for further growth. As we have already referred to, the corresponding hyphae found in *R. subcorticalis* may serve as absorbing organ, and it would not be quite phantastic to assign the same function to the similarly originated hyphae of the endophyte.

The hyphae of the third region may perhaps correspond to those in the "digestive cells." However, in the present object, the digestion of the hyphae seems to contribute but very little to the nutrition of the host,

since the hyphae present are not massive enough to have any concern with it. It seems that the hyphae of the second region substitute for them in this respect by undergoing self-disorganization. The important function involved in these hyphae is, on the other hand, the transmission of the food materials from the outer strand and of decomposed substances of the hyphae developed in the second region.

### VIII. Relation between the Rhizomorph and Potato-Tuber.

During the present investigation I had an opportunity to examine potato-tubers attacked by the rhizomorph strand. The relation between these plants offers very interesting facts which bear more or less upon the problem of the mycorrhiza of *Gastrodia*, as might be expected from the resemblance of the vegetative organ which both higher plants possess.

The connection of the potato-tuber and the rhizomorph seems to be of usual occurrence on farms near or in woods. Prof. MIYABE first informed me that he found in Hokkaido the association of these plants. Afterwards I obtained such material in Nikko where I had been several times to make field observations on *Gastrodia*. The farm from which I got the material is surrounded by uncultivated grassy land with shrubs and trees, containing abundant humus substances. *Rhizomorpha subterranea*, originally developed at this place, has spread throughout the farm. At a glance the connection of the rhizomorph and potato appears quite similar as in *Gastrodia*, showing as if they form a mycorrhiza (Fig. 15). The fact, however, is contrary: the fungus is typically parasitic upon the potato-tuber. The strand creeping over the surface of the tuber sends out branches which penetrate into the inner tissue, developing then as *Rhizomorpha subcorticalis*. White silky mycelia may be recognized from the surface traversing the subcortical layer in radial direction from the infected point. Besides, the soft brownish strands spread out through the tissue near the cortex. The portion of the tuber so far traversed by the fungus becomes brownish and loses turgidity, show-



ing disintegration (Fig. 16). It shows the symptom of soft rot which the potato-tuber suffers usually from parasitic fungi or bacteria. The composing cells of the diseased portion are easily crushed between the fingers. There are also observed the hyphae entering the cell cavity. The infected cell contains brownish cell sap, and the starch grains remain intact for certain periods of time. In its whole aspect the behaviour of the fungus is quite the same as when it attacks the *Gastrodia*-tuber in such a state to which I have attributed the parasitism of the fungus.

It may be noted that the parasitic connection of the fungus with *Gastrodia* happens only as an exceptional case, while it is usual with potato, so far as observed by me. The comparative study of the tuber from both plants recalls our attention on the critical point in which the parasitism is turned into the symbiosis. While the anatomical characters are quite the same in both tubers—presence of the thin corky layer and thin-walled parenchymatous nature of the composing cells, packed with starch grains—the fungus seems to exert upon them quite the same mechanical or chemical actions. The difference whether parasitism or symbiosis is established depends upon the reaction of the host to the attack of the fungus. The state of affairs in potato is only that the living plasm easily succumbs to the devouring action of the fungus, while in *Gastrodia* the plasm responds otherwise, that is, it restores its high activity, by which it is able to subdue the fungus in favour of itself. It must be remembered, however, that *Gastrodia* is sometimes under unfavourable conditions to respond to the attack, then the fungus manifests its proper parasitic action.

## IX. Development of the Tuber and the Mycorrhiza Formation.

Although the facts gained from the cytological studies are sufficient to prove *Gastrodia* to be a mycorrhizal plant, the precise mode of its life is yet far from being adequately explained. The presence of numerous isolated tubers, from the full grown to such in very young stages, without



connection with the fungus seems to obviate the absolute necessity of the symbiotic association, and one might think that an intact young tuber can absorb the food material from the surrounding medium to enable it a complete development. In order to settle this point, I attempted to follow by culture-experiments the fate of such tubers. The material was collected in the flowering season, and the tubercles apparently free from the fungus were transplanted in different places or in soils of different kinds, and their subsequent condition was watched carefully.

### 1. POT CULTURE.

At the end of May the tubercles were planted in pots with loam, humus soil, or quartz sand. No subsequent growth in thickness of the tubercle was ever found; but usually its apex grows out into a long slender rhizome, often producing at the same time a few offsets directly on the node of the mother-tuber. Approaching the end of the vegetative season the offsets were also developed on the rhizome. In all the cases the offset-tubercles were provided with pedicels. When the vegetative season was over, the pedicel, rhizome, and even the mother-tubercle began to disintegrate altogether, and the offsets were all set free, so that at this time they must absolutely stop their growth.

Figs. 6 and 7 show the process of development of offsets from the mother-tubercle. In these figures *a* represents the development of the mother-tubercle attained at the beginning of the experiment (May 29). Examined on July 9, the apex has already grown up to the rhizome (10 cm. long in Fig. 6) and small processes have appeared on the surface of the tubercle. On August 9, the development has proceeded as shown in *b*. When examined in the spring of the next year (April 15), the result was as may be represented in *c*. We see here the decay of the mother-tubercle, rhizome, and pedicel, the surviving portion being represented only by the offsets. Compared with the mother-tubercle the offsets are yet exceedingly small, expressing, as it were, the first stage of their growth. I think that they have already come to this stage at the end of autumn and remained unchanged till the next year.

We understand from these facts that the nutritive substances used for the formation of the offsets are evidently derived from the reserve materials stored up in the mother-body. However, as the latter is quite incapable to utilise additional materials from the soil, the offsets must be insufficiently nourished and remain in an incomplete state of development. That the offsets derived from the mother-tubercles free from the fungus are universally in such a condition, as ascertained by repeated experiments, will be strong evidence for the view that the intact isolated tubercle is not able to add any self-assimilated product to the food material gained before isolation from the mother-body.

From the result of this experiment the origin of numerous small tubercles found in the field will be so evident as to demand no further explanation. They appear to be at the developmental stage, but in fact they are at the end of growth. Most of them may remain unsuccessful in the mycorrhiza formation. They perform, however, an important function, the vegetative reproduction, in the way mentioned above. Such tubercles proceed generation after generation to produce much smaller offsets, until perhaps their reserve materials become so much reduced as to be incapable of feeding the offsets derived from.

## 2. CULTURE IN THE FIELD.

One set of intact tubercles was laid in the humus soil near the trunk of oak-trees, where numerous strands of the rhizomorph were found ramifying, while another set was buried in the soil near the oak or other trees, where no apparent development of the rhizomorph could be ascertained. The development of the tubercles thus prepared has proceeded as follows:

1. A few tubercles, all about 6 cm. in length, were laid at the end of May, 1908. Observed on October 28, the specimens in the soil not traversed by the rhizomorph strands have already decayed, after producing a few exceedingly small offsets hardly attaining 1-2 mm. in diameter. On the other hand, the specimens laid at the root of the trees, around which vigorous development of the rhizomorph has taken place, were still

alive and their apices have elongated into branched rhizomes, while no increase in thickness of their body was visible. The rhizomes appeared to be directed towards the trunk of the trees, on whose bark were seen especial ramifications of the strands. I could not ascertain the organic connection of these tubercles with the rhizomorph. But, as a remarkable fact, I found on a piece of a flowered tuber laid together with these tubercles a firm attachment of the strands; yet neither the growth of this piece itself nor the development of offsets has at that time been possible to observe.

Examined in the next year (April 19, 1909), I found that all the tubercles have completely decayed and the dead tissue has been attacked by the strands.

The failure to get surviving offsets from these tubercles must be due to an unfavourable condition under which they were laid. I repeated then the same experiment in the next year.

2. At the end of May, 1909, five vigorous tubercles, on average 5-6 cm. long, were buried, being wrapped altogether in cloths, under the oak-trees at the same place as the previous experiment was carried out. Examined on September 6, vigorously growing strands of the rhizomorph have perforated the cloths and ramified among the tubercles. Three of them have died away without previous production of surviving offsets or effecting the connection with the strands. One of the remaining tubercles has also died, leaving two or three small offsets. The last one, on the other hand, was still fresh and indeed has accomplished the organic connection with the rhizomorph. Two or three rhizomes, 2 mm. thick and a few centimeters long, have developed from it, some carrying small offsets. Though its subsequent development was not observed, it became clear that the rhizomorph had occasion to come into contact with the tubercle and to enter into the formation of the mycorrhiza.

Besides these tubercles, I put into the ground at the same time a certain number of flowered tubers, still fresh but exhausted of their reserve materials in forming the flower shoot, under a trunk of the same trees. In September they all collapsed and the rotten bodies were



traversed by numerous strands of the rhizomorph. The fungus appeared to utilise the organic substances from the dead tubers.

The most remarkable and conclusive result was obtained with a tubercle 7 cm. long, which has been treated similarly. In September numerous strands had already attached firmly to one portion of its surface, and their branches penetrated into the tubercle and produced a large mass of hyphae spreading in wide extent under the subcortical tissue. Within that extent the cortex of the tubercle assumed somewhat coarse consistence and appeared in the surface view light brownish and more or less verrucose. The tubercle did not show its own growth, but produced a few offsets as shown in Fig. 14. The offset developed near the centre of the mycorrhizal cell region showed the most vigorous development, attaining about 4.5 cm. in length and 2 cm. in breadth and indicating the rapid subsequent growth. The other offsets were smaller and the rudiments of their body were represented as small processes on the apices of the pedicels.

As this specimen was used for cytological study, its subsequent development could not be observed, but we may judge from the stage so far attained that the largest offset would have grown up to the flowering stage, though the smaller ones could not.

Supporting this view I found in the field at the end of the next month an isolated large tuber, so large and so full of starch as the flowering one. Its apex bent upwards, representing the rudiment of a flower shoot. As this tuber was quite free from the attack of the rhizomorph, the full size it attained and the accumulation of sufficient reserve materials must have been due entirely to the mycorrhizal mother-tuber, which had already disorganized, but whose presence was learned by a scar left on the base of the new tuber. Comparing this tuber with the offset reproduced in Fig. 14, it seems highly probable that the former represents the subsequent stage of the latter.

We have learned from the above experiments that the organic connection with the rhizomorph may be accomplished by tubers of various sizes. So in the field, as in the culture-experiment, I could find the flower-



ing tuber attacked by the rhizomorph (Fig. 13). However, this is perhaps an extreme case, since the tuber at such a stage does not generally demand the association with the fungus. The anatomical study shows that the organization of the mycorrhiza is not yet complete: the extension of the endophyte round the infected spot is very narrow, the third region of the mycorrhizal cells is not yet invaded by the fungus, and secretion bodies do not appear. So that there is no indication that the tuber profits by the presence of the fungus. I found also in the field (in May) very small tubercles showing connection with the rhizomorph (Figs. 9-12). Whether the connection was effected in the preceding year (autumn) or shortly before the observation could not clearly be made out. Yet the internal relation between the two symbionts was already so intimate as we can state with certainty that vigorous metabolic activity was taking place. In this case my observations were not so far extended as to confirm whether such small tubercles can grow by themselves in virtue of symbiosis or whether they proceed simply to produce under this condition the offsets attainable to flowering state like the tubercle shown in Fig. 14. To settle this point we must await further investigation.

On the basis of the experiments and observations so far carried out, I come now to make the following statements:

The flowered tuber does not produce the offset-tubercle, but all tubers not yet attained to the stage to bear flowers, whatever mycorrhiza is formed or not, are capable to multiply themselves by producing offsets. With tubers free of the mycorrhiza formation the offsets are produced on long rhizomes. The offsets derived from such tubers are always smaller than the mother-body. It is only the mycorrhizal tuber that can produce the offsets capable to grow up to bear flowers. As a rule, the nutritive connection of the offsets is closed at the end of autumn when the mother-tuber disorganizes. The connection of the rhizomorph with these isolated offsets takes place quite occasionally, and a great majority of them is incapable of further nutrition, so that their descendants, if equally unsuccessful, will be extinct at length after certain generations. This may be shown in the following table.



## X. Discussion.

1. Adaptation towards symbiosis. In numerous mycorrhizas studied by previous authors, it has been generally acknowledged that the fungus undergoes a certain modification; its endophytic portion changes more or less the structure, and the reproductive organ is degenerated. Especially in the fungus forming the endotrophic mycorrhiza, it has gone so far that many investigators entirely failed to find such a process of development as to express its systematic position. In fact, even in the ectophytic fungus, which in symbiotic adaptation stands in lower rank than the endophytic one, the normal development has been found only in very rare cases.

With this point in view the fungal symbiont of *Gastrodia* affords quite an unusual case of symbiotic association. In performing the endophytic development, it receives but little modification: the structure of the hyphae is essentially the same in and outside the higher symbiont, and the fruit body is formed regularly. This may be due to the condition that the symbiotic association of the fungus is accomplished simply by a branch of the vegetative organ, and it does not interfere with the organization of the main portion which exists as a rule in saprophytic and often parasitic form. It may be considered, therefore, that the fungus shows the least morphological adaptation in performing the symbiotic association among the fungi related to mycorrhiza.

On the other hand, the higher symbiont presents the most advanced adaptation and differentiation towards the habit of symbiotic saprophytism. The root system has wholly degenerated, and the tuber, serving typically as a reservoir of food materials, is disposed to perform the absorbing function by the co-operation of the fungus. Special cell layers are then adapted for entertaining the endophyte, and further they are differentiated into different regions. Thus in the present case the mycorrhiza is formed by the less modified fungus and most specialised higher plant. The inequality of adaptation in both symbionts tends to show that the one symbiont (higher plant) requires in great measure the pres-

ence of the other (fungus), while the latter demands by no means the association with the former. It is perhaps connected with this unbalanced state of mutualism that the symbiotic association of these plants takes place less frequently. Again, connected with the latter fact, the production of numerous offsets in the higher symbiont may be assumed as an ingenious device of adaptation for reproduction, whereby the descendants may find an unfailing occasion to associate with the fungus at that place which the ancestor found as fittest for existence.

2. Evolution of mycorrhiza. The fact that *Armillaria mellea* may become parasitic under certain conditions, even when it comes in connection with its symbiotic component, will show that it is a less accommodated fungus as symbiont and its symbiotic development may be considered as a deviated representation of parasitism, taking place quite occasionally or accessorially. From this we can get a clear idea on the evolution of mycorrhiza. Under special circumstances the parasitic life of the fungus is modified so as to cause a reciprocal interchange of benefit with the host, and thus mycorrhiza is established. *Armillaria mellea* may be reckoned as an example showing the first step of such modification.

Similar instances have already been known. PENZIG ('85) reported the results of GIBELLI's observation that the mycorrhizal fungus of the chestnut-tree can under a certain condition destroy the host. MACDOUGAL ('99, p. 5) states, "REES and FISCH call attention to the fact that the relation of a fungus to the root of a specific plant is not always a fixed one. The chemical interchange may be so evenly balanced during a part of the season, or during a part of the lifetime of the fungus or of the higher symbiont, as to constitute a symbiosis; but in other stages the presence of the lower form may result in positive damage or disadvantage to the higher plant. Thus MACFARLANE concludes that the mycorrhizal fungus of *Philesia* is an ultimate disadvantage to the plant, since it hastens the death of the absorbing organs." ELENKIN ('97) conceived the symbiosis as a balanced form of life of two inmate organisms, in which the one may under certain conditions overcome and act unfavourable on the other. NADISON ('08), discovering that the mycorrhizal fungus of



*Quercus* is useless to the host and even acts destructive, pronounced the view that the symbiosis of the fungus on the so-called ectotrophic mycorrhizal root represents a form and stage of parasitism. BERNARD and BURGEFF found a similar feature in orchids, and NEMEC ('04) and GARJEANNE ('11) in rather inconstant association of fungi and the Hepaticaceae. On the basis of these facts SORAUER ('09) has gone so far as to announce the view that parasitism is a form of symbiosis (p. 377). The state of affair in the case of *Gastrodia* will be that the parasitic *Armillaria* infects *Gastrodia* as it does potato, but under ordinary conditions the host subdues, unlike the latter plant, the fungus to make it behave as a symbiont, while under other conditions symbiosis is turned into parasitism, showing the fluctuation of nutritive dependency between two organisms.

Viewed from the point of the evolution of mycorrhiza, we must rank the *Armillaria* in the most primitive form of symbionts. For, not only does it retain yet saprophytic and parasitic properties, being parasitic even on its symbiotic component, but its vegetative and reproductive organs receive but little modification in becoming the symbiont. Those fruit-producing fungi of ectotrophic mycorrhizas which aid always their components in favourable ways may be regarded as being a little more adapted for symbiotic life, while next come such epiphytic fungi that are degenerated so much as to be unable to produce the fruit bodies, and so on.

3. Nutritive relation. In the endotrophic mycorrhiza the nutritive condition of the higher symbiont remains still in confusion. With a symbiont as *Neottia* (MAGNUS, BURGEFF), where the connecting hyphae do not regularly develop, its nutritive connection with the soil is not clear. But most of the endotrophic mycorrhiza possess the connecting hyphae to which the function of the conduction of all soluble substances necessary for nutrition of the higher plant may be possibly ascribed, as asserted recently by BURGEFF. The mycorrhiza of *Gastrodia* may be regarded as a type having the most perfect connecting hyphae among the endotrophic mycorrhizas, and there is no doubt in believing that the direct communication of the nutritive substances from the outer medium to the

host takes place in the same degree as in the ectotrophic mycorrhiza. Supported by anatomical studies, we must consider the physiological condition as being a combination of that found in ecto- and endotrophic mycorrhizas. So that FRANK'S view of the nutritive process as similar to insectivorous plants may be partly justified in this case, but for the chief food materials which the higher symbiont requires for vigorous growth the portion of the fungus lying outside the symbiont must be concerned in the first rank.

We may here consider the nutritive reciprocity between the fungus and the orchid. What kind of profit can the fungus receive from the higher symbiont? It is not conceivable that the higher symbiont behaves beneficially towards the fungus with constant supply of carbohydrates, as do greenish symbionts. Allowing the disappearance of starch and the consumption of the protoplast of the host to be advantageous to the fungal development, we cannot conclude that these processes have a great weight on the whole organization of the fungus. For, the food materials of the fungus are usually supplied by its portion developing as *Rhizomorpha subcorticalis* outside the symbiont; this is true even when one of its strands forms symbiosis. Thus in the fungus the importance of the symbiotic association is not indicated.

The case is, however, contrary in *Gastrodia*. The absence of the root system and chlorophyll apparatus, and also other characters make the association with the fungus absolutely necessary for existence. About the real nature of nutrition, whether the orchid absorbs all the nutritive substances from the fungus or the presence of the fungus enables it to assimilate the organic or inorganic matters afforded by the environment, I have not yet experimental proofs. Still it is certain that the essential constructive materials do not enter the tuber through the cork tissue developed on its surface for protection. Rather I would like to think that, unlike any greenish mycorrhizal plant in which self-assimilation may possibly occur, or colourless higher symbionts which possess, though more or less degenerated, an absorbing organ, *Gastrodia* must derive its nourishment exclusively from the fungus. That the raw materials as well as

organic substances, which are available for the higher plant, are conducted through the fungus is evidenced by the nature of the fungal organ come in direct connection with the higher plant. According to BREFELD ('77), *Rhizomorpha subterranea* is a transferer of nutritive substances, or a stolon, "In der Erde ernähren sich diese Stränge selbst nicht, sie sind nur Ausläufer, quasi Stolon vom Mutterstock,..." (p. 149) and "die *Rhizomorpha subterranea* ist eine secundäre Bildung von der *Rh. subcorticalis*, sie wird von dieser, die in Bäumen lebt, unterhalten, bis sie selbst einen Baum erreicht und in diesem zur Selbständigkeit gelangt" (p. 149). *R. subterranea* becomes in the present case a bond between *R. subcorticalis* and *Gastrodia*, through the agency of which the nutritive substances are transferred from the former to the latter.

We arrive now at the conclusion that the interchange of the nutritive substances, or the reciprocal profit, is not in equilibrium; in *Gastrodia* the loss of starch and protoplast is amended by the gain in excess from the fungus and *vice versa* in the latter. Considering the whole organization of both symbionts, the fungus appears not to demand the symbiosis, while *Gastrodia* must absolutely depend upon it. In strict sense, therefore, true symbiosis is not conceivable; *Gastrodia* is in fact parasitic on the fungus, otherwise the symbiosis shows such a tendency.

This argument may be supported by the structure of the vegetative organ which *Gastrodia* possesses, quite comparable to that of holoparasites, such as the Balanophoraceae, Rafflesiaceae, etc. These parasites, as a matter of obvious fact, are entirely depending in their nutrition upon the root of green plants. Local hypertrophies occasioned on the host may point out the existence of a certain symbiotic relation between the host and parasite. Such a beneficial action of the parasite, if I may be allowed to use this word, is comparable, I believe, to the favourable action of *Gastrodia* towards its host, the fungus, for its endophytic development. So that the parasitism involved in *Gastrodia* should be understood in the same sense as is realised in the holoparasites referred to.

The view of parasitism of the higher plant upon the mycorrhizal fungus



was pronounced by FRANK ('92, p. 267), supported by KERNER ('00, p. 242), in *Monotropa*. This view was accepted by some writers (JOST, '08, p. 284) and objected to by others. MACDOUGAL's objection ('99, p. 32), though it may be true as far as *Monotropa* is concerned (cf. PEKLO, '08), appears not to be justifiable in the present case, and the special structure in *Gastrodia*, especially non-development, unlike *Monotropa*, of an absorbing organ, seems to enforce FRANK's argument. It may be assumed in the present case that the moment by which two organisms are brought into contact is the parasitic property of the fungus, but the same property possessed by the higher plant being stronger, the nutritive dependency becomes to be displayed in a reversed way.

As already mentioned, the chief reserve material in the tuber of *Gastrodia* is carbohydrates, especially starch. This surplus product beyond the requirement of immediate consumption is greatest in amount, when its mother-body is symbiotic with the fungus. As to the source of carbohydrates in a non-chlorophyllous higher symbiont, GROOM ('95b, p. 359) maintained the possibility of utilising certain organic compounds from the surrounding medium through the surface of its own body. Referring to the plants provided with the absorbing organ, like *Thismia*, *Monotropa*, etc., this view might perhaps be justified. But in the subterranean part of *Gastrodia* the development of the cork tissue seems to preclude material communication with the surrounding medium. In my opinion, the starch of the higher symbiont originates from glycogen (see ERRERA, '06) or other carbohydrates found in the fungus body. The "exoenzyme" of BURGEFF, which makes the organic substance in the soil available directly for the higher plant, does not account for the absorption of carbohydrate in this case. The nitrogenous substances will be taken up from the fungus in the form of secretion bodies. If the tuber be able to assimilate the free nitrogen as ascertained in some mycorrhizas, it will enter mainly through the fungal strand. Further, if the presence of the endophyte increases in fact the concentration of the cell sap of the host, as BERNARD and BURGEFF maintained in the mycorrhizal orchids, it may be perhaps favourable to *Gastrodia* for facilitat-



ing the absorption of soluble materials from the fungus. STAHL ('00) clings to the view that the endophyte promotes the absorption of salts in mycorrhizal plants, which otherwise is usually insufficient due to reduced transpiration. In *Gastrodia* this apparently necessary supply of salts would be established by the fungus body itself. Thus all the substances necessary for *Gastrodia* can possibly be supplied by the fungus. This conclusion is not inconsistent with several facts we have gained from anatomical and biological studies, so that it will show approximately the real nature of the mycorrhiza in *Gastrodia*.

4. Fructification of the fungal symbiont. The normal development of the fruit body in the mycorrhizal fungi is hitherto known, so far as I am aware, only from the epiphytic ones (REESS, '85; WORONIN, '85; NOAK, '89; KAUFFMAN, '06; PENNINGSTON, '08; etc.). The identification by culture was successful with some fungal symbionts isolated from greenish plants (BERNARD, '09; BURGEFF, '09; PEKLO, '09, '10), but it appears to me that most endophytes in non-chlorophyllous plants have so much degenerated as to be incapable of the normal development in a culture medium (see BURGEFF, '09, p. 205). Notwithstanding, the fungal symbiont of our colourless orchid, though partly endophytic, shows the normal development of the fruit body like some ectotrophic mycorrhizal fungi on green plants. From this we now come to rank *Armillaria mellea* in the mycorrhizal fungi and to take it as an additional species to the flora of fungi concerned in the Orchidaceous mycorrhiza, from which BERNARD and BURGEFF have isolated only *Rhizoctonia* (*Hypochnus*).

5. Other allied orchids. The peculiar phase of symbiosis found in *Gastrodia* may call attention to the nutritive condition of *Stereocandra* and *Galera*, the tropical orchids which have quite similar vegetative organs as *Gastrodia*. Systematists (BLUME, '58) described the isolated flowering tuber of these plants, which appear to me, judged by such a phase seen on the basal end of the tuber as there is shown an attachment surface, that they have been connected formerly with the mother-body. They seem to be nourished like *Gastrodia* by the mycorrhizal mother-body until detached. In his studies of monocotyledonous saprophytes GROOM

('95a), however, reported in *Galera nutans* (*Epipogum nutans*) that there are outside the rhizome "densely matted masses of fungal hyphae" (p. 191); scale leaves investing the whole surface of the rhizome produce long hairs into the soil, through which the hyphae enter the scales and occupy "all the cells" of them (p. 195); and "scales are the absorbing organs of the plant" (p. 195). The scales of the *Gastrodia*-tuber do not produce the hairs, nor is the mycorrhizal fungus found in them, though some fragmented scales are infected with hyphae which have no concern with symbiosis. GROOM's investigation is sufficient to prove the mycorrhiza of *Galera*, but more detailed accounts seem highly desirable to attach much physiological importance to the fungi he found in the scale leaves.

Thus the combination of *Gastrodia* and *Armillaria* establishes an unusual type of mycorrhiza. Several notable facts thus far gained from the studies during the vegetative reproduction suggest to us the importance of undertaking researches about the development of this orchid from the seed. As to the condition of the germination of the seed and the structure of the seedling we are yet quite ignorant, and the problems attached to them are the relation between the fungus and the germination of the seed, the structure of the seedling, the form of the fungus which infects the seedling, the development of the tuber from the seedling, the process of development from the seedling to the flowering state, etc. I anticipate among these points some peculiarities relating to mycorrhiza, which will deserve to be made public by a second communication.

## XI. Summary.

1. The vegetative organ of *Gastrodia elata* is represented simply by a tuberous rhizome. It forms mycorrhiza with the mycelium strand of *Armillaria mellea*, generally called *Rhizomorpha subterranea*.

2. The cytological features tend to show the mycorrhiza to be an endotrophic form. However, the direct connection of the endophyte

with the rhizomorph strands vigorously vegetating in the surrounding medium indicates the physiological relationship between the two symbionts to be similar to that in a typical ectotrophic mycorrhiza.

3. The infection by the fungus is effected by a sucker-like branch of the rhizomorph strand, which penetrates the cortical cell-layers of the tuber, partly compressing the underlying cells and partly dissolving their walls.

4. The infecting strand sends out separate hyphae which spread intracellulary in a definite zone under a few layers of subcortical cells. The extension of the endophyte is limited within a certain area around the infected spot.

5. The mycorrhizal cell-layers may be distinguished into three regions, according to the structure of the cells and the nature of the hyphae which compose them. The first region consists of the outer two or three layers which contain a densely entangled mass of comparatively thick-walled hyphae. A similar convolution of hyphae is observed in the next one or two layers composing the second region. In this region the hyphae are generally thin-walled and of various breadths, and are often arranged in pseudo-parenchymatous form. The innermost layer constitutes the third region; the cells are the largest and contain each a few, slender, less curved hyphae.

6. The different hyphae of the endophyte have essentially the same structure as those composing the rhizomorph strand.

7. The hyphae of each region show characteristic alterations. They are permanent in the first region, but they undergo self-disorganization in the second, leaving their walls as irregular masses, while in the third region they are mostly consumed by the host-cells.

8. The walls of the mycorrhizal cells undergo certain chemical and physical changes. In the first region they become lignified and in the second they are partly dissolved by the perforating hyphae. In the third region the walls become thickened but do not undergo any chemical modification. Further, in both the first and third regions the wall develops a tubular sheath which shows a distinct lignin reaction.

9. The thick-walled hyphae of the first region also give lignin reaction.

10. In the mycorrhizal cells the amount of the cytoplasm and the size of the nucleus are increased previous to the infection of the fungus. After infection the protoplast is soon consumed by the fungus in the second region, but in the first region the cytoplasm invests the hyphal clump and the nucleus is stretched, often so much as to cause fragmentation into two portions. When the clump becomes larger, the protoplast disappears entirely.

11. In the third region the cytoplasm increases further in amount, and acquires a granular and dense consistence, while the nucleus undergoes hypertrophy, hyperchromatophily, and various deformations by constriction. The constricted portions may be often pulled apart in a stellate form.

12. In the third region there appear prominent bodies, which may be considered to comprise both secretion and excretion products of the endophyte. First, light yellowish, oil-drop-like globules become visible in the cytoplasm. At the same time, there appear similar-sized vesicles with a hyaline membrane and containing yellowish granules. They are both secretion-bodies, or if not, their derivatives, to be consumed later by the host. While these are disappearing, there occur innumerable small, hyaline, irregular masses, each in a vacuole of the cytoplasm. Afterwards they are thrown into a large common vacuole and by fusion form an irregular mass, more or less resembling the so-called clump ("Klumpen") usually found in the digestive cells of many mycorrhizal plants. Probably they are derived partly from the remnant or ground-substances of the secretion-bodies and partly from the undigested wall of the hyphae, and, judging from their resistant property, they are certainly useless excreta.

13. In the third region an accumulation of very fine granules is observed round the hyphae, previous to their disintegration. Probably it is a phenomenon connected with the digesting action of the host.

14. The cell of the third region is certainly a metabolic centre of



the higher symbiont, where the food materials are elaborated. The remarkable alterations in the cytoplasm and nucleus are indications of the great activities that are going on in the cell during this process; so that, when the latter is over, the nucleus resumes its original form and structure, while the cytoplasm again becomes fibrous and vacuolate.

15. There is no evidence that the larger secretion-bodies are direct derivations from the swollen portion of the fungal hyphae, so that they are not organs similar to the vesicles or sporangioles known in many mycorrhizas. They are due to the accumulation of substances secreted by the fungus into the cytoplasm. The globules seem to originate partly from the protein contents of the degenerating hyphae in the second region, while the vesicles are derived from the material elaborated by the fungus.

16. Starch grains disappear from all the mycorrhizal cells. However, in the third region they reappear with the cessation of the metabolic activity.

17. The rhizomorph, besides forming mycorrhiza, behaves as a true parasite towards *Gastrodia*, and under certain circumstances the strand penetrates deeply into the tissue of the tuber, then developing as *Rhizomorpha subcorticalis*. The infected tissue collapses and is apparently injured, as may be seen in potato tubers attacked by the same fungus.

18. *Gastrodia* multiplies usually by the tuber. It produces long rhizomes from its apex or node, upon which are developed stalked offsets. Sometimes the latter are produced directly on the nodes of the mother-body.

19. At the end of autumn, the mother-body and the pedicel of the offset undergo degeneration, so that the daughter-tubercles are all set free separately.

20. The association of the tuber with the rhizomorph takes place quite occasionally. If the mother-tuber forms mycorrhiza, it can derive a full-grown offset which remains dormant during the winter and develops the inflorescence-axis in the spring of the next year. Otherwise, the offsets cannot grow larger than the mother-tuber, and under this condition the offsets would become smaller and smaller in successive generations,

until they are so much reduced in size and deficient of food materials as to be incapable of further multiplication.

21. The production of numerous offsets from a mother-tuber may be considered as a favourable adaptive device for distributing the descendants over a wide area and for giving them better chances to combine with the fungal symbiont.

22. The tubercles cultivated in the pot with sand, loam, or humus soil produce, as in the field, numerous offsets, but none of them can reach the flowering stage. This shows that they have no ability to provide themselves with nutriment from the surrounding medium.

23. The usually saprophytic development of *Armillaria mellea*, the extremely reduced vegetative organ of *Gastrodia*, and the cytological features involved in the symbiosis lead us to the view that the reciprocal exchange of nutritive substances between the two organisms is not equal, *i.e.* the fungus becomes the victim of the orchid, perhaps receiving from the latter but little benefit for its whole organization. Therefore, it appears probable that physiologically the relation of *Gastrodia* to the fungus is similar to that of subterranean holoparasites to their host-roots—*Gastrodia* is parasitic on the fungus.

24. The chief reserve material stored in an adult tuber is starch. When intact, the grains give a red brownish colour with iodine, but in the paste form, both amyloid and amyloextrin reactions become distinct, giving a violet or reddish violet colour.

25. The amyloplast in the mycorrhizal cells and in all subcortical cells outside them contains a heavily staining body of nuclear nature.

April, 1911.

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## EXPLANATION OF PLATES.

## PLATE I.

- Fig. 1. Adult tuber of *Gastrodia elata* with a growing flower shoot.  $\times 1/2$ .  
 Fig. 2. Inflorescence-axis with racemose flowers.  $\times 1/2$ .  
 Fig. 3. *Rhizomorpha subterranea* found around the tubers of *Gastrodia*.  $\times 1/2$ .  
 Fig. 4. Living stock of *Quercus serrata* with numerous rhizomorph strands creeping over the surface of the underground portion of the trunk and of the main roots.  $\times 2/5$ .  
 Fig. 5. Fruit bodies of the fungal symbiont, *Armillaria mellea*, developed on the dead stump of the oak at the same locality as *Gastrodia*.  $\times 3/5$ .

## PLATE II.

All figures in this plate are given in natural size.

Figs. 6, 7. Development of young tubercles without association of the fungus. *a*, at the end of May; *b*, at the beginning of August; *c*, at the beginning of April in the next year. At the last period the nutritive connection of the offsets with the mother-tubercles has been interrupted.

Fig. 8. Rhizome-like tubercle.

Figs. 9-12. Small tubercles accomplishing an organic connection with rhizomorph strands (obtained from the field at the end of May).

Fig. 13. Adult flowering tuber occasionally attacked by the rhizomorph.

Fig. 14. Mycorrhiza formation of a tubercle laid under the oak-tree in May and its formation of an offset in vigorous development (observed in September).

Fig. 15. Potato-tuber attacked by the parasitic strand of *Rhizomorpha subterranea*. Affected portion shows collapse of tissue and discolouration.

Fig. 16. Section through the affected portion of the same, showing the distribution of the strands as *R. subcorticalis*.

## PLATE III.

Fig. 17. Section of a mycorrhizal tuber, showing the connection of rhizomorph strand and the endophyte, the distribution of the mycorrhizal cells, and secretion as well as excretion bodies in the cells of the third region. The strand is shown in transverse section. *a*, *b*, *c*, first, second, and third layers of the composing cells; *f*, *s*, *t*, first, second, and third regions; *n*, nucleus; *w*, surface view of the cell wall; *g*, globule; *v*, vesicle; *e*, excreta or small body; *st*, starch grain. Triple stain.  $\times 100$ .

Fig. 18. Secretion of the globular bodies from the hyphae of the third region. Fuchsin iodine green.  $\times 900$ .

Fig. 19. Globule (green) and excretion bodies (red). Fuchsin iodine green.  $\times 900$ .

Fig. 20. Distribution of the hyphae in the cell of the third region through the lignified wall. Numerous excretion bodies lie in the vacuoles. The nucleus is shown in section. Fuchsin iodine green.  $\times 400$ .

Fig. 21. A portion of the cell of the third region at the latest stage. Excretion bodies are fused together, and starch grains reappear. Triple stain.  $\times 400$ .

Fig. 22. Corruption of the hyphae, producing excretion bodies. Triple stain.  $\times 900$ .

Fig. 23. Limiting wall between the second and third regions, and the connection of hyphae between the two regions through the lignified papilla. Fuchsin iodine green.  $\times 900$ .

Fig. 24. Secretion of the globular substance from the hyphae of the third region. Some globules are granular. Triple stain.  $\times 900$ .

Fig. 25. Granular region round the hyphae of the third region. Triple stain.  $\times 900$ .

#### PLATE IV.

The left side of all the figures of the host-cells given in this plate corresponds to their upper side.

Figs. 26-29. Mycorrhizal cells of the third region.

Fig. 26. Stage before infection, with a very small amount of protoplast packing numerous starch grains.  $\times 300$ .

Fig. 27. Early stage of the infected cell, producing a large vesicle which contains a dense mass of granular substance, and also producing numerous globules. Cytoplasm is dense and excretion bodies are beginning to appear on its peripheral portion.  $\times 300$ .

Fig. 28. Nearly the same stage, showing the distribution of the hyphae and their secreting action. Round the hyphae is seen a distinctly granular region.  $\times 300$ .

Fig. 29. Later stage. Cytoplasm becomes more vacuolate in the peripheral portion and the number of the excretion bodies is increased, while the globule and vesicle diminish their contents.  $\times 300$ .

Fig. 30. Central portion of a mycorrhizal cell of the same region in the last stage of its activity. Cytoplasm assumes a network structure and the nucleus is disintegrating, while the excretion bodies gather in common vacuoles to fuse together.  $\times 300$ .

Fig. 31. Mycorrhizal cells of the second region, showing the development of the hyphae and their devouring action of the protoplast.  $\times 300$ .

Fig. 32. Hyphae of the second region approaching to disintegration. The content appears as a fine filament, and nuclear bodies are seen here and there.  $\times 900$ .

Fig. 33. The hyphae of the same region in the process of self-disorganization.  $\times 900$ .

Fig. 34. The same hyphae almost entirely disorganized, leaving their wall as structureless remnant.  $\times 400$ .

Fig. 35. Mycorrhizal cell of the first region, with hyphal clump surrounded by the cytoplasm. Nucleus is fragmented into two portions.  $\times 400$ .

Fig. 36. Mycorrhizal cell of the same region, showing the formation of numerous tubular sheaths on the limiting wall between the first and second regions.  $\times 400$ .

Figs. 37-39. Amyloplast in normal subcortical cells of the mycorrhizal tuber, showing the successive enlargement by the accumulations of starch and accompanying change of the nuclear body  $\times 900$ .

Fig. 40. Enlarged amyloplast in the cell just below the mycorrhizal cell, with the correspondingly enlarged nuclear body.  $\times 900$ .

Fig. 41. More enlarged amyloplast in the inner tissue of the tuber, showing disappearance of the nuclear body.  $\times 900$ .

Fig. 42. Nuclear bodies of the amyloplast at successive stages (*a-d*).  $\times 2600$ .

Fig. 43. Granular globules and small vesicles closely arranged. Globules stained with safranin are figured darkly and vesicles which take on gentian violet are shown in light tint. A large globule is found close to them.  $\times 900$ .

Fig. 44. Relation between the hypha and globules as well as vesicle. Two globules are produced laterally and one terminally after the formation of vesicle.  $\times 900$ .

Figs. 45-46. Successive secretion of globules from the hyphae, laterally and terminally. Apparent empty portion of the hyphae is surrounded by the granular region.  $\times 900$ .

Figs. 47-48. Formation of the vesicle as terminal swelling of the hyphae.  $\times 900$ .

Fig. 49. Disintegration of the hyphal branches into small granular bodies.  $\times 900$ .

Fig. 50. Disintegration of the hypha into excretion bodies at the end of activity of the mycorrhizal cell.  $\times 900$ .

Fig. 51. The wall of an empty vesicle beginning to shrink.  $\times 900$ .

Figs. 52, 53. Later stage of the same having undergone much shrinkage.  $\times 900$ .

Fig. 54. Excretion body in irregular form.  $\times 900$ .

Fig. 55. The same in homogeneous consistence.  $\times 900$ .

Fig. 56. The same, one showing the probable derivation from the wall of the vesicle and the other from the matrix of the globule.  $\times 900$ .

Fig. 57. The same in irregular form.  $\times 900$ .

#### PLATE V.

Fig. 58. Nucleus of an intact cell of the first region.  $\times 900$ .

Fig. 59. The same shortly before the infection of the hyphae.  $\times 900$ .

Fig. 60. Much deformed nucleus of the mycorrhizal cell of the same region.  $\times 900$ .

Fig. 61. Nucleus of an intact cell of the second region.  $\times 900$ .

Fig. 62. The same shortly before the infection of the hyphae.  $\times 900$ .

Figs. 63, 64. Resting nuclei of the normal cells, showing the relative size with those of the mycorrhizal cells.  $\times 900$ .



Figs. 65, 66. Nuclei of intact cells of the third region.  $\times 900$ .

Fig. 67. The same shortly before the infection of the hyphae, showing the deformation and fragmentation of the nucleolus.  $\times 900$ .

Fig. 68. Much deformed and enlarged nucleus in the cell of the same region at the highest activity.  $\times 900$ .

Fig. 69. The same highly stretched out.  $\times 900$ .

Fig. 70. The stretched portion of the same, showing the arrangement of chromatin threads in a bundle.  $\times 900$ .

Fig. 71. A portion of the nucleus at the same stage, showing the arrangement of chromatin at both constricted and stretched portions.  $\times 900$ .

Fig. 72. Transverse section through the stretched portion of the nucleus at the same stage, showing the bundle of chromatin threads in the centre.  $\times 900$ .

Fig. 73. Peripheral portion of the tuber, showing the development of the infection branch of the rhizomorph strand and its influence on the structure of the underlying cells. The mother strand on the surface of the tuber is shown in longitudinal section.  $\times 150$ .

Fig. 74. Inner tissue of the tuber traversed by the parasitic strand of *Rhizomorpha subcorticalis*. The strand is shown in transverse section.  $\times 150$ .

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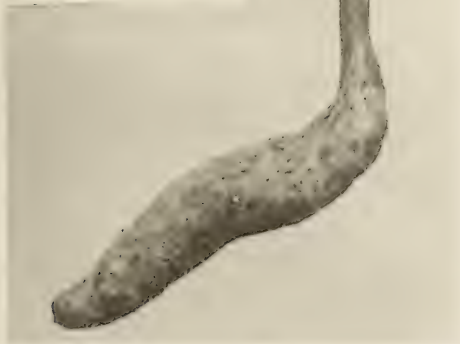
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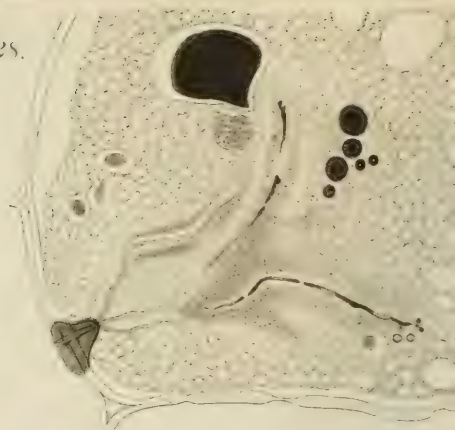


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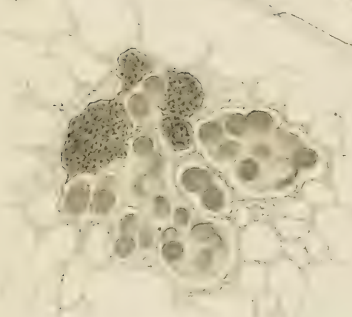
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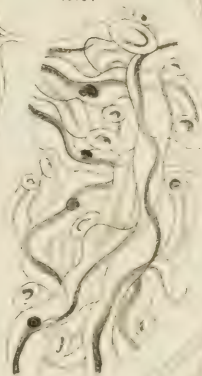
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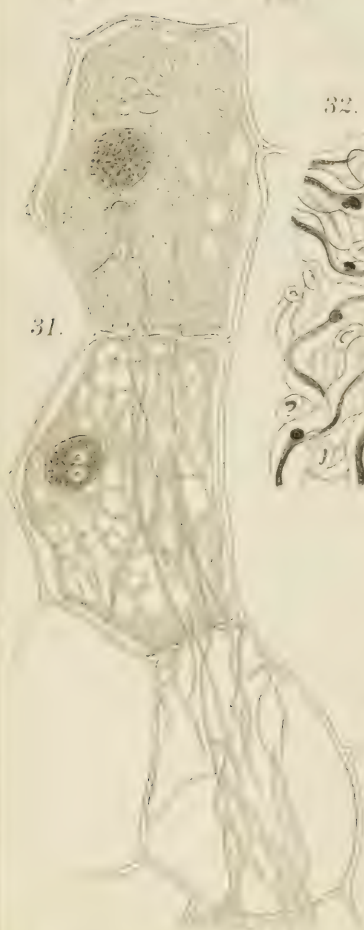
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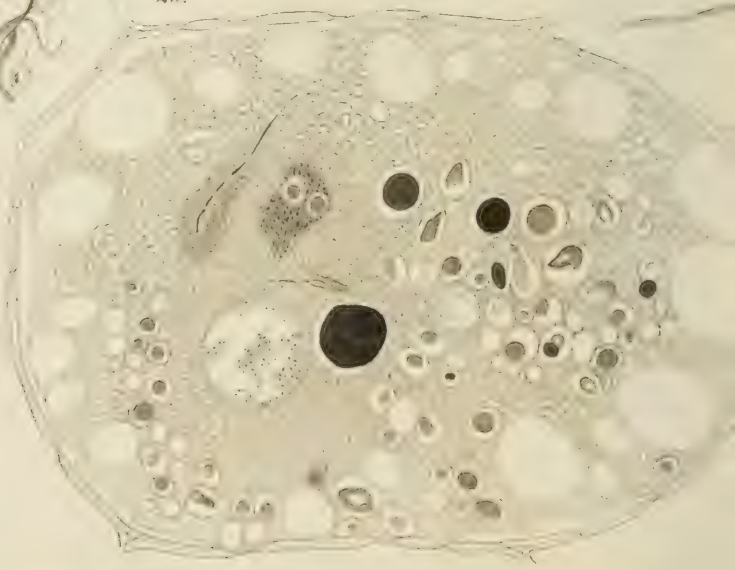
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# On the Root-Cotton, a Fibrous Cork Tissue of a Tropical Plant.

BY

**S. Kusano.**

With Plates VI and VII, and one Figure in the Text.

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The material for the present study was first brought back by Mr. G. NAKAHARA in 1905 from Botel-tobago Island ("Kotosho") about 36 miles east from the southern part of Formosa. It consists of a mass of the cottony fibre developed on the root of a tree, botanically unknown at that time. On account of it having too strange a structure, he was once of opinion that the fibre might be an abnormal tissue produced by the action of certain parasites or other agents. So far the material he has kindly placed at my disposal was concerned, I could not give an account on this tissue beyond its anatomical structure. Having occasion to visit the same island in the winter of 1908, during the botanical excursion to Formosa with a grant from the Imperial University, I could fortunately examine myself a large number of the living plant in question at several places and make a closer observation on the development of the tissue in question. I now venture to state that it is indeed the most interesting root tissue, normally developed and, so far as I know, not yet recorded. The most important points we have to deal with about this tissue may be its biological significance and physiological function, but I must here dismiss them from consideration until further experimental evidence is to hand. What is aimed at in the present article is rather to give the nature, the anatomical structure, and the development of the fibre, as I believe that even this information may stimulate a considerable economic, if not botanical, interest.

To Messrs G. NAKAHARA and U. NAMIKI I am indebted for their courtesy in sending me the valuable material, and my best thanks are due to the authorities of the Imperial University for enabling me to make the excursion and also to the Government of Formosa for much assistance and hospitality offered me while travelling in that island.

### Description of the Plant.

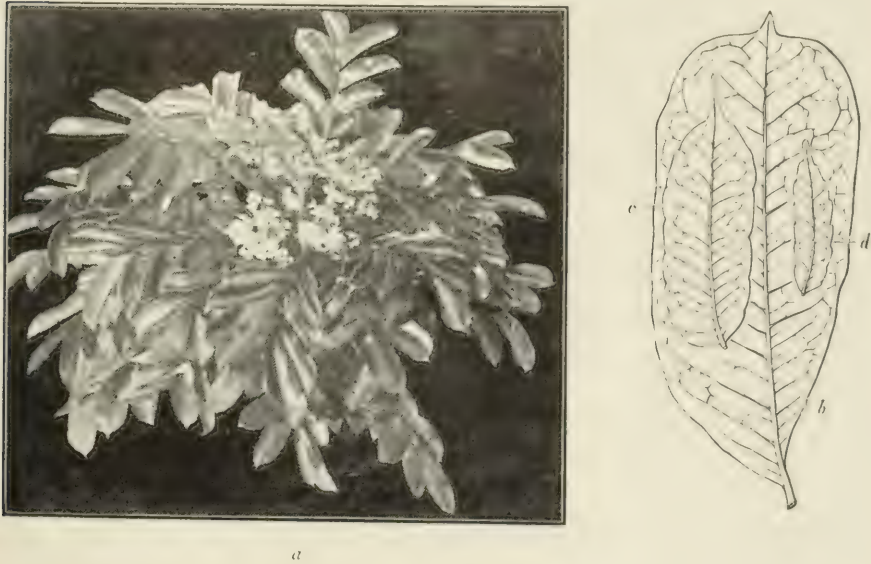
The cotton-producing tree belongs to the Rutaceae and was first described in 1906 by MERRILL ('06, p. 68) under the name of *Fagara integrifoliola* on the specimen collected in the Philippine Islands. This tree shows in external form certain individual variations; in particular is there a great difference between young and old plants. So that it will not be superfluous to note here the points I was able to observe on the living material.

In Botel-tobago it is a rather common tree growing among other trees and shrubs on the mountainous slopes. I found it at several places near the valley region. The trunk is straight, and rather thick branches have alternate leaves clustered on the apical portion (Text-fig. 1 *a*). In a several years old trunk the pinnate leaves are, so far observed by me, a little smaller than those described by MERRILL, being almost 50 cm. in total length, and are provided with a less number of leaflets, usually in 7 pairs. However, their general form and texture agree precisely with his description, except that no spines are ever found, which he described to be present, though very few, on the common petiole (*b*).

Most remarkably, a young tree, 1-3 years old, differs much from the older one in external appearance, so much that, without the aid of an intermediate form, it is hardly possible to identify it with the species noted. The stem is provided with short but thick spines irregularly distributed on its surface, while they are lacking in older trunks, though in the latter MERRILL mentioned the development of spines in any young

1 For identification of our plant I am obliged to Mr. MERRILL, for which I express my thanks to him.

branch. Further, the leaflets (*d*) are oblong with obtuse but distinct serrations, gradually acuminate apices, and symmetrical thin blades, which are all different, as MERRILL already described, in the leaves from an old trunk. The leaf has a larger number of leaflets, generally 8-9 pairs. In neither young nor old trees have I been able to find spines on the leaf, though they occur in the Philippine specimen.



Text-fig. 1.

*a*, inflorescence and clustered leaves on the top of a branch; *b*, leaflet of an old tree; *c*, leaflet of a young tree; *d*, leaflet of a seedling (*b*, *c*, *d*, 1/2 nat. size).

The structure and form of the leaves undergo a gradual change until the tree reaches a certain age. In the final state the leaflets are glabrous, shining, subcoriaceous, entire, strongly inequilateral at the acute base, and abruptly acuminate at the apex. The blade is provided with pellucid spots and has a characteristic smell.

In this dioecious plant a few panicular axes developed from the upper axils of each branch carry dichasium flowers. No spines are found on the axes. Flowers are white and very fragrant owing to the presence of nectary at the base of the ovary. Their diameter measures 8 mm. They

have pedicels, 2-3 mm. long, subtended by a few small bracteoles. Sepals 4, pale green, small. Petals 4, oblong, white but often becoming later pale reddish at the basal portion. In male flower stamen 4; filament short and thick; anther pale yellow; pistil rudiment. In female flower pistil 1, greenish; style nearly wanting; ovule 2, hanging. Capsule ovoid, 8-10 mm. long, with soft verrucose pericarp and hard endocarp, dehiscing through the suture line, one seeded. In other respects the reproductive organs agree in structure with the original description by MERRILL.

In Formosa it is hitherto known only from Botel-tobago. According to Mr. MERRILL's kind communications, it is common in the Philippine Islands, extending from Mindoro Island to Batan Island in the Batanes group, the most northern part of the Philippines and very near to Botel-tobago.

In Botel-tobago this tree flowers in winter. I saw in December the trees all in full blossom. Mr. NAKAHARA collected unripe seeds in February. The specimen collected by Mr. NAMIKI at the end of March was still immature. He could obtain the ripe seed first in July.

### Description of the Fibre.

The fibre which I am going to describe under the name of "root-cotton" is the derivative of the root of *Fagara integrifoliola*. Over the whole surface of the root system, with exception of slender, one year old roots, the fibre is produced abundantly running radially to the long axis of the root and forming such loose bundles as of silk fibres or asbestos (Figs. 1, 2, 5-7). The bundle can be easily torn off with the fingers into separate fibres. The quantity of this cottony fibre produced from one root varies with the age of the latter; in an old thick root it attains a considerable thickness, but the outer older portion of the fibre in direct contact with the surrounding soil is decaying successively and, according to the rate of decay and of the growth of the fibre, the thickness cannot be constant in the roots even of similar size or the same age. The thickest layer which I have obtained from an old root



was 6 cm., discounting the outer half-decaying portion. The whole mass of the cotton is easily stripped off from the hard, living cortex of the root, leaving a clean and apparently uninjured surface (Fig. 3), and thus no sign can be observed that the spoliation would interfere with the activity of the root.

The fibres consist of separate filamentous rows of exceedingly thin-walled, empty, and elongated cells (Fig. 14). The diameter of the constituting cells is nearly uniform, measuring  $25\ \mu$  in average, but their length varies considerably according, perhaps, to the conditions of the root, some attaining to  $250\ \mu$ , while others being nearly isodiametrical. Each fibre is interrupted at certain intervals by a varying number of thick-walled, light-yellowish, compressed cells (Fig. 15). These cells, lying at equal height in all fibres, are all connected with each other side by side and form a node-like constriction to the bundle. In a transverse section of the root such cells are found to arrange in concentric rings (Fig. 6). The fibres are not often separated easily and are broken at this portion in tearing.

The fibres are light straw-coloured and have a silky lustre. They are exceedingly fine, soft and weak, and may be easily pulverised between the fingers into a fine waxy powder. On this account they cannot be used for spinning. In compact mass they are more elastic than cotton wool (*Gossypium*). The most remarkable qualities, by which the root-cotton may be distinguished from other vegetable fibres, are its unwettability and less hygroscopy. When a bundle of the fibres is put on the surface of water, it floats forever, and if immersed in water, driving the air out of the fibres by pressing them with the hand, it soon comes on the surface without being penetrated by the liquid, while the commercial cotton wool treated similarly is wholly saturated with water and sinks down sooner or later. A piece of cobalt paper (cobalt chloride) wrapped in the root-cotton does not discolour in a few minutes when immersed in water, though one wrapped in cotton wool reddens in the same interval of time. Further, while in the latter case, after one day, the paper is found saturated with water, in the former it is simply moistened and

discoloured. From this experiment we see that the moisture may penetrate the cotton fibres through the air interstices between them, but no water is absorbed by a capillary action as in cotton wool.

Under the microscope we observe that the cell wall is absolutely impermeable to water, so that the fibre immersed in water leaves the cell cavity quite vacant. It does so also to alcohol, xylol, and ether; unless heated, the air in the cavity is not replaced by them.

To compare the absorptive power of moisture in the root-cotton and the commercial cotton wool, I placed a nearly equal mass of them in a moist chamber and in a steam steriliser, and the following result was obtained:

Water absorbed in percentage by weight.		
	In a moist chamber for a week (max. temp. 22°C).	In a steam steriliser for 3 hours; left in till the next day.
Root-cotton .....	16.2	26.1
Cotton wool .....	15.2	20.3

Thus when calculated in percentage by weight, the root-cotton is more hygroscopic than the commercial cotton. However, it must be noted that the specific weight of the root-cotton is much smaller; when the equal bulk of a compressed mass is compared, the commercial cotton is twice as heavy than the root-cotton. So that, an equal mass being taken into comparison, it is found that the latter fibre is less hygroscopic than the former.

As to the chemical nature of the wall the fibre gives the following reaction towards several reagents. In the experiment, cork tissue, cotton wool, and wood-fibre were used, when necessary, for control.

1. Phloroglucin + HCl: reddish violet colouration is very clear as in the cork tissue from *Quercus variabilis* and *Q. suber* used for control.
2. Aniline sulphate: yellowish colouration.
3. Iodine and sulphuric acid: orange brown or orange colouration.
4. Caustic potash: light yellowish colouration.
5. Heated in a concentrated solution of caustic potash the wall is

insoluble. After washing with water chlorzine-iodine solution gives blue colour.

6. Concentrated sulphuric acid: blackens but insoluble.
7. Concentrated nitric acid: soluble when heated.
8. Concentrated chromic acid: soluble in ordinary temperature.
9. Copper oxide ammonia: insoluble.
10. Alkanin solution in 50% alcohol: faintly coloured like the cork tissue.
11. Sudan III (treated according to KÜSTER): faintly coloured.

It follows from these results that the wall of the fibre consists essentially both of lignin and suberin, and the unwettability is due to the suberisation. It may be noted, however, that the thick-walled cells in the filament of each fibre do not show any lignin reaction, being composed chiefly of corky substance. On the whole, the root-cotton is a homologous tissue to the ordinary cork developed on the bark of trees.

### Application.

This peculiar cotton has long been familiar to some of the natives and is used by them for certain purposes. The natives of Botel-tobago are acquainted with its unwettability and use it largely as an indispensable material for building boats. Since the instrument in preparing the boards for the boat is only a small axe made by themselves, it is not easy to make the connecting sides of the boards so smooth as can be done by means of a plane. To keep, therefore, the boat water-tight they caulk the seams with this cotton fibre. During my visit to the island I could watch personally the building of a boat, and saw a large quantity of the cotton stapled for this purpose.

It is not yet known whether the cotton is used by the natives in the Philippines for such purpose. But that they find a certain application for it was ascertained by the kind information of Mr. MERRILL: according to him, the cotton is used in Mindoro Island for stuffing pillows.

It would be quite natural to find that with the natives of the tropics the application is highly restricted owing to their simple mode of life. To civilised people, however, the properties possessed by the cotton will suggest further uses. As the principal character of the root-cotton is comparable to the cork bark from the cork oak, which everywhere is now largely used for technical purposes, it will possibly become, by further studies, an important material for industry. I am sure that the unwettability and lower hygroscopy make it suitable as a substitute of cotton wool or other fibres as stuffing or wadding material. The pressed sheet of this cotton may be further substituted, for certain purposes, for the cork plate or sheet.

To prepare the refined cotton we have simply to remove the soiled particles attached to the outer surface of the raw material, and, if necessary, to bleach it. The cotton, unlike the ordinary cortex of roots, is less spoiled by the soil, and is easily cleaned after drying or washing with water. Considering the inexpensive process of cleaning and the less laborious gathering in, I am inclined to the view that the root-cotton may become an important forest product in the tropics.

### Development of the Root and the Fibre.

The youngest portion of the root is comparatively thick, measuring 1.5-2 mm. in diameter, and has apparently a smooth surface (Fig. 1). The root-hairs are quite wanting. The epidermal cells protrude into papillae, whose outer wall, however, being verrucosely thickened, appears incapable of allowing, or at least making very difficult, the passage of soluble matters from the outside (Fig. 10).

Immediately below the epidermis the exodermis is developed which consists of one layer of the thick-walled cells (Fig. 10 *ex*). The thickening of the wall takes place mainly on the outer and lateral sides, leaving the inner side unthickened. Between the exodermis and the central cylinder there are large, round parenchymatous cells of the primary cortex. Most of them are inhabited by a mycorrhizal fungus. In the



endotrophic mycorrhiza we find connecting hyphae passing through the epidermal cells into the soil. The endodermal cells are thin-walled and provided with CASPARY'S dots (Fig. 10 *c*). The central cylinder consists of 7-9 vascular strands surrounding a central pith with lignified wall (Fig. 10 *m*). A group of 2-3 sclerenchymatous elements is developed later accompanying each phloem portion (Figs. 11, 12, *sc*).

At a later period of the vegetative season, or at the beginning of the next, the phellogen arises from the pericycle (Fig. 11 *ph*). It produces towards the inside loosely arranged phellodermal cells (*pd*) and towards the outside cork-cells of a tabular shape (*c*). The latter cells are afterwards stretched out in longitudinal direction, while each radial row of them is detached from each other along the longitudinal wall, and thus gives rise to a separate fibre (Fig. 13). The elongation of the cells is usually less in younger than in older roots. The root-cotton developed in this manner shows, like the cork bark, an alteration of longer thin-walled with compressed thick-walled cells which unite laterally and form a node, as noted above, on the fibre-bundle (Figs. 5-7, 13, 17). However, it does not mark regularly annual growth. It appears to me that the thick-walled layers are formed repeatedly in each vegetative period as may be seen from Fig. 17, which shows the cotton fibre developed on a two year old root. Still I am of opinion that the formation of this layer is more or less connected with climatic conditions, for in the material collected by both Mr. NAKAHARA and myself, all in the winter months, the innermost layer of the cotton consists, in almost all parts, of the thick-walled cells, which attach, when the cotton is stripped off, to the surface of the root. Their compact arrangement can certainly perform a protective function towards the naked cortex (Fig. 3). In the specimen collected at the end of March I observe the beginning of formation of the thin-walled tissue under them.

In the whole mass of the cotton taken from an old root no interposed dead remnant of the cortical tissue is found. This points out clearly that the phellogen can be active for a long time. However, after the removal of the primary cotton, the cortex, if it is covered with soil,

produces at a certain depth from the surface a secondary phellogen which, after developing exceedingly thick-walled cork-cells, develops the cotton as before. Thus we can harvest the cotton annually or every few years from the same root. It is stated by the natives that a too old root will gradually produce a smaller amount of the cotton. Thus, with regard to the mode of development, we find strict agreement between the root-cotton and the cork bark from the cork oak.

The development of the cotton seems to depend in great measure upon the condition of the root. The less vigorous root produces a less amount of the cotton and of bad quality on account of its being a compact mass intermixed with many layers of thick-walled cells. The cotton of such kind gives often a texture as of the common cork bark. We see also on the same root a vigorous or less vigorous development in different years according perhaps to the environment or inner conditions.

### **Structure of the Cortex of the Stem.**

The anatomical study of the root, having shown the general similarity of the cotton to the root bark, gives us an impetus to compare the stem and the root of this tree regarding the bark formation. It is observed that numerous longitudinal fissures appear on the surface of branches already in the same year they developed, and cause the epidermis to die assuming a dark brownish colour. The wound thus produced becomes covered with light yellowish cork tissue, forming most apparent stripes running longitudinally over the surface of the branch. In appearance this cork tissue does not differ from that developed in lenticels which are found usually on fissures. The microscopical examination shows at once that the development of these cork cells in the stem goes on quite similarly as in the root. In the very young stem, as for instance, of a seedling, the periderm is already formed under the epidermis, which consists essentially of the thin-walled cells. But the first few layers of the peridermal cells developed on the cortex in the youngest branch of an old trunk consist of cork-cells having rounded

apices and a yellowish wall exceedingly thickened on the upper and lateral sides, often so much as to leave the cell cavity as a slit (Fig. 16). These cells are followed by thin-walled tabular cork-cells, phellogen, and phelloderm successively. On the fissure, however, no such thick-walled cell-layers precede the thin-walled ones; the phellogen produces directly the latter which are somewhat elongated and easily separated laterally from each other. These cells may correspond exactly in structure to those of the root-cotton. The only difference is that the cells on the fissure do not elongate into filamentous rows and form rather a pulverous mass. The structure of the lenticel is quite typical and the complementary cells have essentially the same structure as the cork-cells appearing on the fissure. They are usually interrupted by the closing layers which are continuous with the periderm and are composed of thick-walled tabular cells just as those in the root-cotton (Fig. 18).

Thus we see that the root-cotton is strictly homologous to the cork tissue developed on the lenticel or the fissure. The former is only characterised by the massive development and by the longer constituting cells.

A closer affinity to the root-cotton is afforded by the wound cork on the stem. When the cortex is wounded in wide extent, the tissue on the exposed surface dries up. Under this dead tissue arises the cork cambium from the uninjured cells and derives vigorously cork-cells outside, which upheave the overlying dead tissue and come afterwards in sight as a soft straw-coloured coating (Fig. 4). It may often attain to 3-4 mm. in thickness and appears more fibrous than the same tissue arising from the fissure, but far less so than the root-cotton.

### General Remarks.

The root-cotton is a kind of cork tissue derived from the cork cambium which arises primarily from the pericycle or secondarily from the secondary bast of the root. Histologically, no essential difference exists between the root-cotton and the cork tissue normally developed on



the aerial axial portion. However, so massive a production of such tissue on the root leads us to inquire as to what function does it perform on the organization of the root system? At first sight it may be referred to some extent to certain kinds of tissues which have already been described by several writers in plants under special conditions. SCHENCK ('89b) gives a full account on the histology and physiology of the aerenchym. He states that it is of a wide occurrence in water- and marsh-plants, and he regards it as an apparatus especially adapted for respiration, the activity of which cannot be maintained otherwise. There occurs in the respiratory or aerating roots of certain Mangrove-trees a spongy tissue which, having special aerating passages, may be considered as performing a similar function (SCHENCK, '89a; GOEBEL, '86, '89; KARSTEN, '91). Further, the pneumathodes (JOST, '87) of a lenticel-like structure often developed in roots, either submerged or in a swampy soil, may also be included to the category of respiratory apparatus. KARSTEN ('91) proposes to call all these similarly functioning tissues or organs by the name of "pneumatophores." According to WIELER ('98) the submerged roots of certain trees develop protuberances which are homologous to lenticel, but differ from it in origin of the composing cells, being derived under the cork cambium. Although in the arrangement of cells the root-cotton resembles closely the aerenchym, the structure of the cells diverges widely: in the aerenchym they are invariably living, containing protoplast and cell sap, and having an unsuberised thin wall, but in the root-cotton they are dead, containing air inside the lignified as well as suberised wall. These characters show rather a close affinity of the root-cotton to the pneumathodes (GOEBEL, '91; SCHENCK, '89b). Thus, viewing it from the anatomical features, the root-cotton is not in exact coincidence with any tissue above referred to. Physiologically, however, we find a certain relationship, since the unwaterability, leaving the air space inside, enables it for gaseous interchange. Yet we are far from being able to prove conclusively that it is really called forth into existence with such a respiratory function. For, the surrounding medium is widely different from that to which the occurrence of the above named



tissues is chiefly due. As far as was ascertained by myself in Botel-tobago, *Fagara integrifoliola* is one of the usual forest trees, and in spite of an abundant rainfall throughout the year and constantly moist climate, its root system, spreading out near the surface of the ground in slopes, appears to be so sufficiently aerated as to demand no special respiratory apparatus, in contrast to the plant organs in water or swampy soil. On the basis of the fact that quite a similar tissue occurs ordinarily in wounds or lenticels on the aerial axes, the root-cotton should be rather regarded as a peridermal tissue, proper to the axial portion of this tree, and without any special biological significance in connection with the function of the root system. Admitting that it is histologically homologous to any or all of aerenchym, pneumathode, the tissue of respiratory roots, and protuberance of submerged roots and stems, I have a strong inclination to agree with WIELER's view ('98) regarding its true function. In all probability the root-cotton may perform no other physiological function than that it behaves as a bark, being merely promoted for development by the stimulus of the surrounding medium, as announced by WIELER in his discussion on aerenchym and pneumathode. In this connection moisture seems to play an important part. The fact that, in the lower portion of the stem nearest to the ground and kept constantly moist, the development of this tissue is often more vigorous than in the upper portion, may lend support to this view.

Apart from the biological and physiological problems attached to this tissue, it may now be concluded that it is of an economic value for us. At least it can be substituted for cotton wool as stuffing or wadding material. The value of the root-cotton may be chiefly in its unwettable and less hygroscopic quality. Further, compared with the common cotton plants, the planting of this tree and the gathering of the fibre appears to be less expensive. At any rate it must be remarked that this interesting tree may become to foresters the subject of study from an economical point of view.

June, 1911.

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## EXPLANATION OF PLATES.

PLATE VI. ( $\times 2/3$ .)

Fig. 1. Young portion of the root system already producing the root-cotton, except the youngest branches.

Fig. 2. A piece of a thick root covered with the massive cotton fibre.

Fig. 3. Another piece of the same root deprived of the cotton.

Fig. 4. A stem showing the development of the cork tissue on fissures and the wounded surface (upper side in the figure) of the cortex.

Fig. 5. Transverse section of a young root.

Fig. 6. Transverse section of an old root.

Fig. 7. A thick layer of cotton fibres taken from an old root. The upper side in the figure corresponds to the inner layer of the cotton.

Fig. 8. Separate bundles of the cotton fibres.

Fig. 9. Refined cotton fibres.

## PLATE VII.

<i>b</i> , bast.	<i>c</i> , cork-cell	<i>cf</i> , cork fibre.
<i>ct</i> , thick-walled cork-cell.	<i>e</i> , endodermis,	<i>ep</i> , epidermis.
<i>ex</i> , exodermis.	<i>m</i> , pith.	<i>p</i> , pericycle.
<i>pd</i> , phelloderm.	<i>ph</i> , phellogen.	<i>pr</i> , primary cortex.
<i>sc</i> , sclerenchymatous cell.	<i>v</i> , phloem.	

Fig. 10. Transverse section of a very young root with endotrophic mycorhiza.  $\times 150$ .

Fig. 11. Transverse section of the cortex of a young root, showing the beginning of the formation of the cotton fibre from the pericycle.  $\times 300$ .

Fig. 12. Transverse section of a young root, showing the development of the cotton between the primary cortex and the central cylinder.  $\times 12$ .

Fig. 13. Transverse section of a two year old root, showing the development of the cotton fibre from the phellogen.  $\times 150$ .

Fig. 14. Separate cotton fibres.  $\times 100$ .

Fig. 15. Compact thick-walled cells in the fibres.  $\times 100$ .

Fig. 16. Transverse section of the cortex of the stem, showing the development of special cork-cells under the epidermis.  $\times 300$ .

Fig. 17. Transverse section of a young root, showing the cotton traversed with layers of thick-walled cork-cells.

Fig. 18. Lenticel on the stem in longitudinal section.

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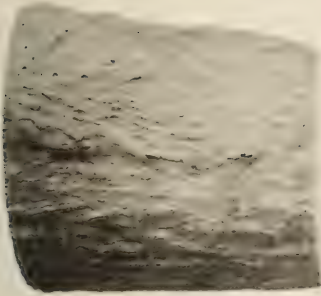
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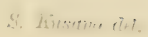
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# Cytological and Experimental Studies in Citrus.

BY

I. Osawa.

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With Plates VIII—XII and one Text-Figure.

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Fertilization is almost always indispensable for the production of fruits and seeds, except in certain parthenogenetic plants. In a few cases, however, plants may normally produce their seedless fruits without pollination; such process is, as is well known, what NOLL has first called "Parthenokarpie" or "Jungfernfruchtbildung." Parthenocarp occurs not rarely in cultivated plants and has been a well known fact for a long time. KERNER (27) informs us that in the Botanical Garden of Vienna pistillate flowers of *Obione halimifolia* produced seedless fruits every year without pollination. MÜLLER (33) observed the same phenomenon in *Hedysmum*. It is stated also by KIRCHNER (28) that the medlar (*Mespilus germanica*) may produce seedless fruits, if pollination is prevented artificially. The same phenomenon was found by MUNSON (35) in egg-plants and cucumbers, described by TAMARI (45) and recently studied by WETTSTEIN (53) in *Diospyros Kaki*, found by KUMAGAI (29) and studied by IKEDA (24) in certain *Citrus* species; quite recently EWERT (10, 11, 12) found also parthenocarp in apples, pears, currants, etc. Besides these, banana, pine-apple, and a few others are said to produce fruits parthenocarpously.

The "Washington Navel Orange" and "Unshu," which are well known varieties of *Citrus*, are most prominent examples which naturally produce seedless fruits. According to IKEDA (24), notwithstanding the fact that pollen grains of these varieties are incompletely developed and sterile, the

fruit may be perfectly developed, but with no seed. As these conclusions of IKEDA are based solely upon field experiments, the morphology and cytology of these *Citrus* varieties are quite unknown.

In my present investigation, I intend to trace out at first the development of pollen grains and embryo-sacs of *Citrus* in general; then to study, whether some irregularities or anomalies may occur in the same processes of "Unshu" and "Washington Navel Orange," and to determine how such abnormal conditions were brought about; and finally to study the relation existing between such irregularities, sterility and parthenocarpy.

Before proceeding further, I have here to express my sincere gratitude to Professor HARA and to Messrs. C. TANAKA and T. TOGASHI, who have kindly supplied me with material, etc.

### Materials and Methods.

My investigation is made mostly on "Washington Navel Orange" (*Citrus Aurantium* L.) and "Unshu" (*C. nobilis*, LOUR.). As both are sterile and parthenocarpous, I have examined for the sake of comparison "trifoliolate orange" (*C. trifoliata*, L.), "Natsu-mikan" (*C. Bigaradia* DUHUM. var. *sinense* G.) and "Asahi" in a few stages; for the embryo- and endosperm-formation trifoliolate orange was chiefly used. The greater part of the material was collected in the spring of 1910—1911, in the orchard of the Horticultural Department of the Agricultural Experiment Station of Kanagawa-Ken at Ninomiya, small collections having also been made in several districts in 1909—1911. All materials of trifoliolate orange were collected in Komaba.

Several fixing reagents were employed, but for very young pistils and stamens, FLEMING's solution and chromo-acetic solution have brought out pretty good results. For ovaries, especially for older ones, acetic-alcohol and CARNOT's fluid were more satisfactory. Before ovaries were dipped into the fixing fluid, both ends of the ovarian wall were carefully cut away to make the contact of the ovule with the fixing fluid easier. In older stages it is sometimes necessary to remove their walls wholly or partly, because the thick wall of the ovary becomes so hard after dehydration, that it is almost

impossible to make thin sections. After remaining in the solution about 24 hours these materials were washed in running tap water from 12 to 24 hours, dehydrated with alcohol, and imbedded in paraffin through chloroform as usual.

With acetic-alcohol and CARNOY's fluid, materials were treated for only 15—20 minutes and then washed with alcohol.

Sections were 5—15  $\mu$  in thickness. For staining, FLEMMING's triple stain and HEIDENHAIN's iron alum-haematoxylin gave most satisfactory results. For the study of embryo- and endosperm-formation DELAFIELD's haematoxylin was sometimes better.

### Development of the Flowers.

The earlier stages of the flower development were studied in "Unshu" and "Navel Orange." As they were similar to each other, except the difference in the number of stamens and carpels, the description given below applies to both, unless the contrary is stated. The earliest stage observed by me is shown in Figs. 1 and 2, in which all parts of the flower are already visible. The outermost protuberances on the receptacle are five sepals, of which some may sometimes fuse to each other. Next come the petals. In this stage both sepals and petals are pretty well developed, overlapping one within another. Within the whorl of these young petals we see a variable number of papillae. In "Unshu" there are eighteen or more. These represent the beginnings of stamens. The innermost whorl is represented by a number of carpels which enclose a cavity with a hemispherical protuberance (*pt*) arising from its base. At this stage the cavity is not yet closed above, and since the thickness growth of the carpellary wall is not equal throughout its whole extent, a number of protuberances are produced. Though the number of these foldings or carpellary leaves is also more or less variable as in the case of stamens, yet we may count generally ten or more in "Unshu" and twelve or more in "Navel Orange."

A somewhat later stage of the floral development is shown in Figs. 3-6, where we see that among others the pistil is especially developed. The lamellar protuberances in the inner surface of the ovarian wall become



more prominent and the inner edges of these protuberances begin to fuse into one another, and also with the central protuberance (*pt*) of the flower. Thus a number of small loculi are formed in the basal part of the pistil. In the upper portion of the carpel, which is destined for the future stigma and style, though the lamellar protuberances are in contact, yet they do not fuse into one another and leave a broad central cavity (Figs. 7, and 8). At the same time the placental outgrowths arise from the inner side of the ovarian cavities, as lateral outgrowths of the central protuberance. The ovary in the next stage is shown in Figs. 8-14. In Figs. 9-14, six parallel cross-sections obtained from different heights of one ovary are shown. At this stage each ovule begins to appear on the surface of the placenta as a small protuberance and gradually protrudes into the cavity (Figs. 15-21), each ovarian cavity producing two rows of ovules (Figs. 13, 14 and 21). In their young stage, there is no indication of the archesporial cell. Just before the primordia of the inner and outer integuments make their respective appearance, the growth of the young ovule becomes unequal at its different sides, so that the apex of the ovule begins to bend upwards (Fig. 16), till finally the anatropous ovule is formed (Figs. 15-21). The mode of development of the ovary in "Navel Orange" is very similar to what has just been stated about "Unshu," but the formation of protuberances in the inner surface of the ovarian wall and that of protuberances at the base of the ovary take place somewhat more irregularly. This can very easily be seen by comparing the longitudinal and parallel cross-sections shown in Figs. 23-30, with the corresponding stages of "Unshu" (Figs. 8-14). The carpellary leaves fuse gradually into one another as in "Unshu," here the mode is somewhat different, inasmuch as new loculi are formed inside and up the original ones (Figs. 31-35), so that we see now two concentric rows of loculi in the upper portion of the ovary (Figs. 32, 35). They develop subsequently into the two rows of juice sacs and produce the "navel" appearance at the apex of the fruit. In these inner and new loculi ovules may appear immediately, though they are more or less irregularly shaped and variable in size (Fig. 35).

During the development of the ovary, that of the anther goes naturally together with it. At an earlier stage, when the carpellary cavity remains open above, the anthers become already round and much enlarged, and when



the ovule appears as a small protuberance the microsporangia of each anther are already discernible. Whereas the inner and outer integuments of the ovule are not yet differentiated, the microsporangia have already the well marked tapetum as well as the pollen-mother-cells, which are then in the resting stage. When the primordia of the inner and outer integuments of the ovule have appeared, the pollen-mother-cells are already in the anaphase of the second nuclear division or even in the tetrad stage, and when the megaspore-mother-cell is in the synapsis, pollen grains are already formed. So that when the flower just opens, the megasporangia are generally yet only two- or four-nucleated, while some do not reach even this stage.

### Microsporangium.

The location of the archesporial cells is indicated by the slightly greater size of their nuclei as well as by their staining behavior towards the staining reagents. Later the differentiation of the anther-tissue into the epidermis, the middle layers, and the sporogenous cells takes place. At first there is no distinction of definite sporogenous cells and tapetum (Figs. 37 and 38), but soon the tapetal cells become distinguishable from the pollen-mother-cells (Fig. 39). In *Citrus* it appears that the tapetum is derived from the original sporogenous cells and that the cells of the middle layers never contribute to the formation of the tapetum; this is clearly seen from the number of the middle layers and from the difference of shape and character between the cells of the latter and of the sporogenous tissue. The number of the middle layers is generally about three in "Unshu", and in "Navel Orange" often more. That the original sporogenous cells contribute to the formation of the tapetum is maintained by many authors, among whom we may mention WYLE (54) (*Elodea*), WEBB (52) (*Astilbe*), LAND (30) (*Ephedra*), COULTER (7) (*Ranunculus*) and SCHATTUCK (41) (*Ulmus*). In the majority of cases the tapetum is one-layered, but sometimes two- or more-layered in some places, and is irregularly shaped, especially in "Unshu" as well as "Navel Orange" (Fig. 93). Every tapetal cell contains one large nucleus at first, but before the pollen-mother-cells reach the synapsis stage, the nuclei divide once mitotically, so that it contains

two nuclei. Though this two-nucleated condition of the tapetal cell persists for some time, very irregular nuclear divisions soon follow and each tapetal cell becomes polynucleated and these nuclei form often closely aggregated masses (Figs. 95, *a* and *b*); similar cases are seen in the figures of BEER (2) GATES (17) and TISCHLER (50). In many cases, the tapetum persists until the pollen-grains nearly assume their definite shape and then begins to disintegrate.

The pollen-mother-cells in the resting stage are easily distinguished from the tapetal and other adjoining cells by their larger size, their large nuclei, and their reaction towards stains. The nucleus then contains one large nucleolus and delicate linin net-works, with many scattered chromatin granules, which are irregular in shape, and the cells are densely filled with cytoplasm (Fig. 40). Shortly afterwards the nucleus reaches the so-called synapsis stage and then the delicate linin fibres contract gradually, accompanied by the chromatin granules scattered upon them, thus finally separating from the nuclear wall. When the contraction has proceeded somewhat, the chromatin granules and linin-fibres increase in density, until there is formed a deep staining irregular mass (Fig. 41). The synapsis stage seems to last for a comparatively long time. The synaptic ball then again loosens itself gradually, thus spinning out a spirem thread, which now lies loosely in the nuclear cavity (Fig. 42). Though I have carefully examined a number of sections in this so-called dolichonema stage the double thread has never been observed. The spirem shortens and thickens gradually and then seems to divide transversely into a definite number of chromosomes. In the earlier stage of their division, some of them are yet connected by delicate linin fibres to one another (Fig. 43), but soon afterwards such fibres become faintly stained and then disappear (Fig. 44). The chromosomes thus produced now arrange themselves in pairs and appears sometimes more or less irregular in form and variable in size, but the details in this respect were not studied.

This so-called "diakinesis" stage is most satisfactory for the study of number of chromosomes. A number of counts shows it to be probably eight for the gametophyte in "Unshu." At this stage one or sometimes two large nucleoli are yet visible, but stain feebly. Soon after both the nuclear wall and the nucleoli disappear and the spindle fibres begin to appear. I have

noticed the formation of the tripolar spindle (Fig. 46), which, however, seems to become soon bipolar (Fig. 47).

The chromosomes which distribute irregularly in the periphery of the nuclear cavity are drawn now towards the equatorial part of the spindle. The latter is long and narrow and pointed at both poles. When the contraction of the spindle-fibres occurs, the daughter chromosomes in the equatorial plate begin their travel towards the poles. In the prophase of the first division I counted again the number of chromosomes in the polar view (Fig. 48), and found them to be eight for the gametophyte as in the diakinesis stage. The chromosomes in the somatic cells, as in the nucellus cells show the number more than fourteen, probably sixteen. So it may be said that the first division of the pollen-mother-cell is the heterotypic and reducing one.

After the daughter chromosomes reach the pole, the nuclear membrane and nucleoli appear and the chromosomes become more or less anastomosed (Fig. 50), but never enter into the true resting stage. This is very soon followed by the second mitosis. The two homotypic spindles, which are formed simultaneously (Fig. 51), are relatively long and narrow and contract towards the poles as in the case of the first mitosis; they are much smaller than in the latter case. The second division is the homotypic equational division as usual, when the daughter nuclei have reached the poles, the nuclear walls are formed around them and the nucleoli make then their appearance. Shortly afterwards cell-walls are formed simultaneously between these daughter nuclei, thus producing the so-called tetrads, which are still enclosed within the wall of the mother-cell (Fig. 53).

The tetrads grow gradually and round off, and then the wall of the mother-cell breaks down, setting the microspores free in the loculus of the anther. The pollen-grain now continues to enlarge and then the exine and intine are differentiated (Fig. 54). Before the dehiscence of the anther takes place, the nucleus of the pollen grain divides as usual, forming the generative and the vegetative nucleus (Fig. 55).



### Megasporangium.

When the young ovule has reached the stage shown in Figs. 16 and 56, a hypodermal cell having archesporial character is already distinguishable from the adjacent cells, owing to its larger size as well as its larger nucleus. When the primordium of the inner integument makes its appearance, this hypodermal cell divides into two by means of a periclinal wall. The outer or micropylar cell resulting from this division is the "tapetal cell," from which a larger portion of the ovarian wall is subsequently produced.

The formation of tapetal layers seems to go, to some extent, parallel with the development of the megaspore-mother-cell. For example, the former is found very often in the three-layered condition, while the latter is in the synapsis; further the former is five- or more-layered, while in the latter four megaspores are produced. The further development of the tapetum proceeds, till it becomes eight- or more-layered (Figs. 70 and 73). So the embryo-sac is now seated pretty deeply in the nucellus tissue, as found also in *Potamogeton* (23), etc.

The inner daughter cell, which is produced by the periclinal division of the archesporial cell and is the incept of the megaspore-mother-cell, grows rapidly, especially in length, and already before the first nuclear division it becomes several times larger than it was originally, and then it is entirely filled up with cytoplasm. Though two or sometimes more megaspore-mother-cells are often visible in *Citrus* yet only one of them develops into the functional embryo-sac. More than one megaspore-mother-cell in one ovule seem not to be of rare occurrence. For example, BOWER found such in the Amentiferae, Ranunculaceae, Rosaceae and others, GUIGNARD in *Ornithogalum*, BERNARD (4), COULTER and CHAMBERLAIN (8), and FERGUSON (14) in *Lilium*, PACE (31) in *Calopogon*.

The nucleus of the megaspore-mother-cell passes during its period of growth through the stages almost identical with those described in the development of the microsporangial archesporium. In the resting stage, the large nucleus has a large nucleolus and fine linin networks, along which numerous chromatin granules are scattered (Figs. 58 and 59). When the nucleus approaches the synapsis, linin is massed together at one side



of the nuclear cavity, and when the contraction proceeds further, these chromatic substances aggregate into a single ball, which stains deeply as in Fig. 61. After somewhat long duration of the synaptic stage the ball begins to loosen gradually and finally produces the spirem ribbon. The latter now becomes short and thick and then develops into the chromosomes, which are clearly distinguishable from one another, just as it was the case in the pollen-mother-cells. Shortly afterwards the heterotypic spindle makes its appearance; it is placed longitudinally, being parallel to the axis of the ovule, but sometimes more or less obliquely. In this stage the exact counting of the number of chromosomes is almost impossible on account of their too close aggregation on the nuclear plate. But very probably there are not more than eight, so it is scarcely doubtful that the first division in the megaspore-mother-cell is the reducing one.

At the anaphase of the first division the daughter chromosomes aggregate closely at both ends of the cell and become more or less anastomosing (Fig. 65). I could not observe the second mitotic figures of these daughter nuclei; in the next stage examined by me, there was already a row of four megaspores. At first these four cells are nearly equal in size, but soon after the following differentiation takes place. The upper or micropylar three cells show signs of disintegration (Fig. 67), the cytoplasm becomes denser and stains more deeply, the nuclei become less chromatic and finally lose their definite outline.

The lowermost or chalazal cell, on the contrary, grows continuously at the expense of the upper three, which are gradually compressed and flattened to represent finally the more deeply stainable irregular masses at the summit of the lowermost functional megaspore (Figs. 67 and 68). Generally the degeneration of the upper three megaspore-cells is simultaneous, but occasionally it appears that the upper two disintegrate previously to the third one (Fig. 69). Such irregularity takes place also in *Apocynum* according to FRYE and BLODGETT (16).

The process of the megaspore formation in *Citrus* takes thus place according to the usual manner, and a similar mode of development has been reported by many authors in the Rosaceae, Polygonaceae, Compositae, Iridaceae, Ranunculaceae, Liliaceae, etc.

The subsequent history of the megaspore shows no essential deviation from the ordinary process. The lowermost cell enlarges gradually and as the increase of cytoplasm does not accompany it, large vacuoles make their appearance, as in Figs. 68 and 71. The two daughter nuclei produced by the first division move gradually towards the opposite poles of the sac and remain there until the next nuclear division begins (Fig. 72). Meanwhile the cell continues to grow, the vacuoles enlarge gradually, and the cytoplasm is now reduced to a thin layer in the periphery of the embryo-sac, except around the nuclei. When the two daughter nuclei have reached their definite size, they divide again almost simultaneously, thus producing four nuclei, which form two pairs, each situated at two extremities of the sac (Fig. 74).

Shortly afterwards, these daughter nuclei again divide and eight nuclei are formed, which are situated bipolarly (Fig. 75). The four nuclei in the upper portion of the sac assume their characteristic arrangement and give rise to the egg apparatus as well as to the upper polar nucleus (Figs. 76 and 77). The three nuclei in the lower part of the sac travel towards the chalazal region to form the antipodal cells. The lower polar nucleus is formed as usual. In *Citrus*, the egg apparatus occupies about one half or one third of the sac and the synergids lie side by side. In many cases each synergid has a large vacuole in its lower end and its very dense cytoplasm stains deeply. The oosphere protrudes down a little beyond the synergids and contains one large nucleus and more or less vacuolated cytoplasm. The polar nuclei soon move towards each other and may remain in contact for a long time near the lower end of the oosphere; it seems that they fuse shortly before fertilization or even later. The maturation of the embryo-sac takes relatively long time as already mentioned, so when flowers open, the embryo sac remains yet in the two- or four-nucleated stage and after a few days reaches the typical eight nucleated condition.

### Fertilization.

Studies of the results of fertilization were carried on only in *C. trifoliata*, excepting the development of fruits. Fertilization appears to occur relatively

late after pollination. In 1911 at Komaba, trifoliate orange was in full blossom in the middle of April and in the material gathered after one or two weeks after blossoming I have never found embryo-sacs, where fertilization was already finished.

Fig. 79 shows an embryo-sac from the material gathered on May 18th, where the egg nucleus is in the resting condition containing two large nucleoli, of which one is probably derived from the egg nucleus and the other from the male one; one synergid is yet intact, while the other is already disorganized on account of the penetration of the pollen-tube, and a few endosperm nuclei are already visible. Thus it will be very probable that the fertilization had occurred not long ago in this ovule. If this is the case, fertilization takes place perhaps about four weeks after pollination. A similar fact was observed by STRASBURGER (44) in a certain *Citrus*. Further details about fertilization were not studied.

### Endosperm.

After fertilization there occurs a great elongation of the embryo-sac and the ovule, accompanying the development of the endosperm. Fig. 79 shows an embryo-sac, where already several endosperm nuclei have made their appearance. These nuclei divide almost simultaneously throughout the whole length of the sac and they are scattered in the cytoplasm, which makes now a thin layer in the inner periphery of the sac (Fig. 83). This stage with free nuclei persists for a comparatively long time. Fig. 85 shows an embryo-sac, got from the material collected on June 18th, where the cell wall of endosperm tissue is already developed in the upper portion of the sac. A great vacuole is there yet to be seen in the center.

### Embryo.

The oospore remains dormant for a relatively long time. In 1911, though fertilization had taken place in the middle of May at Komaba, I found in the materials gathered at the end of May the oospore not yet divided; and the two-celled or six-celled embryos were seen first in those



collected on June 12th. So it seems that the oospore remains dormant for about three or four weeks in general. Meanwhile the great development of the ovule, embryo-sac, and endosperm takes place, which is easily recognizable by comparing the ovule in Fig. 70 with that in Fig. 84. Both the first and second divisions of the oospore are transverse (Fig. 82). Fig. 84 shows a six-celled embryo. The further development of the latter was not observed in detail. In Fig. 85 an embryo with a long suspensor is to be seen.

### Polyembryony.

The phenomenon of polyembryony is very common in *C. trifoliata*. Since the mode of the development is nearly the same as described by STRASBURGER (43) in *C. Aurantium* in 1878, I will not describe its details. When the egg nucleus is yet dormant we see near the top of the embryo-sac a few large nucellar cells easily distinguishable from the adjacent nucellar ones by their larger nuclei, denser cytoplasm, as well as their behavior towards stains (Figs. 80, 81 and 84). Some of them are pretty deeply seated in the nucellar tissue, thus for example two or three layers deep. Nearly at the same time with the first division of the oospore or even later these nucellar cells divide repeatedly and form a number of embryos, which are distinguished from the normal ones by their irregular shape and great variety in size, as well as by the absence of the suspensor.

The number of the embryos formed in this way is of course variable, but four or five are the commonest and the embryo-sac containing only one embryo is rather rare. In one case I could count clearly nine embryos, which were irregularly shaped and very variable in size.

Embryos derived from the nucellar cells are not rarely met with in plants. Besides *Citrus*, we find them in *Frankia*, *Nothoscordon*, *Mangifera*, *Evonymus*, *Colebogyne*, *Clusia*, *Opuntia*, *Alchemilla*, and some others (8).

### Development of the Fruit.

Fig. 86 shows a cross-section of a single loculus of "Unshu" after



blossoming, in which we see many small protuberances appearing on the inner surface of the ovarian wall.

Parallel with the development of these protuberances, which are produced by the division of the innermost cells of the ovarian wall, rapid divisions of the cells seated near them take place, so that the protuberances grow and increase gradually in number (Figs. 88 and 89). They protrude into, and fill up the cavity tightly, thus forming the so-called "juice-sacs" of *Citrus* fruits.

In "Navel Orange," as already described in the preceding chapter, there occurs the multiplication of the number of loculi and carpels. These new carpels protrude into the central part of the fruit, so that the fruit is stretched out and finally split up in its upper portion, and moreover some of these carpels protrude out beyond the top of the fruit. Such irregularity in the form of fruits is sometimes the result of long and careful cultivation; and we see a good example in tomato, e.g., the "Turk's Cap Tomato," which is sometimes grown as a curiosity (1).



Text-fig. 1. Seedlings of trifoliate orange (after a negative TANAKA).

### Seedlings.

In trifoliate orange, the production of two seedlings from a single seed is very common. Both of them are sometimes equal in size and equally vigorous as in text-fig. 1 *a*, *c*, while in other cases one only is large and vigorous, the other being exceedingly feeble (Text-fig. 1*b*). One of these seedlings, of course, has been derived from the vegetative cells. The case of the production of three or more seedlings

from a single seed is rather rare, though a large number of embryos exist in the ovule, as mentioned before.

### **Abnormities and Degeneration of the male Gametophyte of "Unshu" and "Washington Navel Orange."**

In the development of the microsporangium of "Unshu" and "Washington Navel Orange," there occur several irregularities. In "Unshu," as described in the preceding chapter, though the great majority of the pollen-mother-cells pass normally through the tetrad stage, this is not always the case and we see a few irregularities.

Firstly, the sporogenous cells are not formed at all in some microsporangial regions of an anther, which are filled only with parenchymatous cells so similar to those in the middle layers, that it is impossible to distinguish them from the cells of the latter tissue. This irregularity is very common in the anthers of "Unshu," and is limited to one or two loculi in an anther, while the adjoining loculi show the normal appearance as in Figs. 38 and 91, though sometimes in all of four loculi this irregularity may take place (Fig. 102). On account of this anomaly the anthers take very irregular forms, which naturally affect their subsequent growth. As shown in Figs. 38 and 91, all four lobes of an anther are always turned towards one side and give it the characteristic appearance, as commonly met with in "Unshu." The occurrence of these anomalies seems to be rather rare in sterile plants till now studied by various authors.

Secondly, the number of pollen-mother-cells is very variable; in the well-formed loculus we may count nearly ten to twelve, or even sometimes more in a single cross-section, but occasionally the larger portion of the loculus is occupied by the tapetal cells, with only one or two pollen-mother-cells and rarely it may even happen that in some sections we see the whole loculus filled up with tapetal cells, but with no pollen-mother-cells at all. It seems that the degree of such anomaly differs, to some extent, according to the flowers of different individuals, especially in those of different districts or climates.

Even in the normally developed microsporangium, some of the pollen-mother-cells as well as the tapetum may be degenerated very early, when the mother-cell does not yet begin to divide. These cells then lose at first their turgidity and become more or less irregular in form; their nuclei and cytoplasm then begin to stain deeply, showing that the disintegration process has already set in. Such an early degeneration of mother-cells has also been observed in several sterile plants. JUEL (25) and TISCHLER (50) described in a sterile *Syringa* hybrid that degeneration may sometimes begin as early as the synapsis stage. In an *Oenothera* hybrid, GATES (17) also observed the same phenomenon. CANNON (5) has observed in a sterile hybrid cotton that the disintegration takes place sometimes in the resting stage of the pollen-mother-cell.

The cells produced by this degeneration form irregular bodies, which stain dark-red with saframin-gentian-violet-orange, and deep black with iron-alum-haematoxylin (Fig. 96); these bodies are sometimes scarcely visible when flowers open, being pressed up and consumed by the surrounding tissue (Fig. 97). Such an early degeneration of pollen-mother-cells is rather rare, for the mother-cells pass generally through the normal heterotypic and homotypic divisions.

Some deviations are, however, then occasionally visible, for instance, I found sometimes in the loculus, besides normal pollen-grains, a few very small ones with correspondingly small nuclei.

Thirdly, the travel of the chromosomes towards the poles sometimes goes on very unevenly. A similar phenomenon was observed by GATES (17), BEER (2), TISCHLER (50, 51) and by others.

It must be also noted that the stages of development of the mother-cells are widely different in the anthers of one flower or even in the sporangia of one and the same anther. For instance, whereas in one microsporangium the mother-cells may be in the later stage of mitosis or even already divided to four, in the others of the same anther they may be yet in synapsis. In the different anthers of the same flower, the difference of the stages of development may sometimes be much wider than in the *Oenothera* hybrid studied by GATES (17).

In short, however, it may be said that in the development of the pollen-



mother-cell in "Unshu," there are far less irregularities than in the case of several sterile plants observed by many authors till now. For instance, JUEL, (25) and TISCHLER (50) found in sterile *Syringa* hybrids the amitotic division of the mother-cell-nuclei, the occurrence of multipolar spindles in the reduction division, and the scattering of chromatin granules in the cytoplasm, etc. In an *Oenothera* hybrid, GATES (17) also mentioned similar abnormalities taking place occasionally. Besides, BEER (3), CANNON (5), ROSENBERG (38, 39, 40), GREGORY (20), TISCHLER (48, 49, 50, 51), NAKAO (37), and others announced several irregular phenomena, which occur during the development of the mother-cell of the plants.

In the great majority of cases, the free pollen grains are produced in a normal way in "Unshu." But then their disintegration continues up to the flowering time, so we may find many irregularly shaped pollen grains in the loculus of the anthers. For example, pollen grains differ widely in their size and shape. Some of them are very irregular in form and contain very little deeply staining cytoplasm, while others are very small and have very little or no contents at all, indicating that their development has been stopped at an earlier stage. Several other irregular pollen-grains are shown in Figs. 94, 106. Even in such degenerated pollen-grains the wall is generally well developed as in the hybrids of *Syringa*, *Mirabilis* and *Potentilla*. Sometimes we see in the loculi, instead of pollen-grains, deeply staining irregular masses, which are produced by the disintegration of the mother-cells during various later stages of their development. Such disintegration of pollen-grains is not rare; for example, in sterile *Syringa* hybrid it was found that many pollen-grains become "taub," though the tetrad division was generally completed. According to ROSENBERG (38, 39, 40), in *Drosera longifolia* var. *obovata* (*D. longifolia*  $\times$  *rotundifolia*) the greater number of pollen-grains lose their contents in the later stage. TISCHLER (48) has observed that in sterile *Ribes Gordonianum* (*R. aureum*  $\times$  *R. sanguineum*) and *R. Schneideri* (*R. grossularia*  $\times$  *R. nigrum*) the reducing and the homotypic division of the mother-cells are normal and cannot be distinguished from those of the fertile parents, excepting the occasional formation of the extra spindles in *R. Gordonianum*, but the pollen-grains stop soon to grow as in "Unshu." MURBECK (36) found in *Alchemilla*



*speciosa* and *A. alpestris* that though the tetrad-division goes on normally, almost all pollen-grains soon die off, except some few, which have a normal appearance, having, however, no germinating power at all.

In "Unshu" some of the pollen-grains attain their normal size and structure (Fig. 55). They contain two nuclei, one generative and the other vegetative, as mentioned before, and we may sometimes get them to germinate artificially. Transverse sections of the anther in the flowering stage or in a somewhat earlier stage are shown in Figs. 101—105. They are very irregular in shape. Some of them have no loculus, while others have two or three. The dehiscence of the anther sometimes does not take place at all, for it withers pretty early and then the pollen-grains, which never go out from the loculus, die off there.

Greater abnormalities take place in the development of the pollen-mother-cells in "Washington Navel Orange." Normally the sporogenous tissue is formed in young anthers, though in some loculi it is sometimes difficult to distinguish it from the surrounding tissue on account of their close resemblance to each other, as it was also in "Unshu." The number of the sporogenous cells is, however, much greater than in the latter. In some loculi of the anther the sporogenous cells have large vacuoles and relatively small nuclei, as shown in Fig. 108. The growth of such sporogenous cells is not accompanied by that of nuclei and cytoplasm; they lose soon their sporogenous appearance and are destined to disintegrate. But generally the sporogenous cells develop into the normal pollen-mother-cells and the tapetum. The nucleus of the pollen-mother-cell in the resting stage is large and has about the same construction as that of "Unshu." It persists in this condition a relatively long time. Meanwhile the mother-cell enlarges, but the corresponding increase of cytoplasm not taking place, many vacuoles make their appearance. The nucleus becomes gradually less chromatic and never passes into the synapsis stage. Then the pollen-mother-cells show signs of disintegration, for at first the cytoplasm becomes more granular and stains deeply, while the nucleus becomes less chromatic and finally becomes irregularly shaped. Thus all mother-cells lose their turgidity and shrink to deeply staining irregular masses, which also gradually disappear (Figs. 111, 112). At this stage, the tapetum remains

yet generally as a ring-shaped body, which lines the loculus cavity (Fig. 113), but soon after it undergoes disintegration. A cross-section of the anther of "Naval Orange" in its flowering time is shown in Fig. 114, in which large empty spaces are to be seen in loculi. Remnants of the degenerated tapetum and mother-cells are seen there sometimes as irregular bodies, but there is no trace of pollen-grains.

Such an early and complete disintegration of the pollen-mother-cells seems to be very rare and we have only a few such examples in botanical literature. GREGORY (20) found in a sterile hybrid sweet pea that the disintegration of the mother-cell occurs much earlier than in other sterile plants. According to him it takes place generally as early as the prophase, and the development never proceeds further, though the irregular heterotypic spindle may sometimes be formed. MURBECK (36) described in *Alchemilla alpina* and *A. sericata* that the pollen-mother-cells are degenerated before entering into the tetrad-division.

The pollen-mother-cells just previous to their disintegration contain sometimes two or three nuclei as in Fig. 115, but I could not find the figure of the nuclear division, so it is impossible to decide whether the nuclear division is the reducing one or not. But from the fact that the nuclei produced are irregular and sometimes form closely aggregated masses, resembling the tapetal nuclei, it is not impossible that the division is the common equal one or even amitotic. JUEL (25), CANNON (5), TISCHLER (50) and others described that the nuclei of the pollen-mother-cells divide amitotically. Recently SHIBATA and MIYAKE (42) have found in *Houttuynia cordata* that the resting nuclei undergo occasional amitotic division and then the cytoplasm also divides itself, thus producing two daughter cells. In "Navel Orange" the wall formation never accompanies the nuclear division of the mother-cell in this case, so that the nuclei produced are scattered in the cytoplasm as in tapetal cells. When the flower opens, the dehiscence of anthers does not occur often and they begin to wither away as such.

### Degeneration of the female Gametophyte in "Unshu" and "Washington Navel Orange."

Embryo-sacs of "Unshu" and "Washington Navel Orange" disintegrate very often before attaining their full development. The time of their disintegration is very variable. For example, in "Navel Orange" it often occurs that the megaspore-mother-cell shows the signs of disintegration in synapsis or a little later; not only does it then become very long and narrow, being compressed upwards by the surrounding nucellar tissue (Fig. 121), but also its cytoplasm stains more or less deeply. Generally, however, both in "Unshu" and "Washington Navel Orange," the megaspore-mother-cells seem to pass through the heterotypic and homotypic divisions, thus forming a row of four megaspores; soon after, when the upper three are degenerated to form deeply staining masses, the fourth megaspore often becomes a very small feeble looking cell with a small nucleus, which is scarcely distinguishable from the adjacent nucellar cells (Fig 116). Such megaspores seem then soon to go into degeneration. In later stages of development various modes of degeneration may be found. In the later flowering stage or even later, we often find abnormal embryo-sacs in degenerated condition. For example, the nucellus presents sometimes a fissure-like narrow space, in which the degenerated embryo-sac exists as a very small deeply staining irregular mass (Figs. 117, 124). In other cases, though the embryo-sac itself is pretty well developed, it has very poor contents, which stain deeply, thus indicating that they are beginning to disintegrate (Figs. 118, 119). It occurs also not rarely, that the embryo-sac is very small with only one or two nuclei, although it shows no signs of disintegration, while the normal ones are already fully mature (Fig. 120). Further, in extreme cases, no traces of the embryo-sac are to be detected at all in the nucellus.

The early obliteration of embryo-sacs has been already studied by some authors. In 1886 GUIGNARD (21) announced that in a certain *Begonia* hybrid the formation of the embryo-sac may often fail and that in some *Montbretia* hybrid the embryo-sac obliteration sometimes occurs in the early



stage of its development. BARNET describes that the disintegration of the embryo-sac may take place in *Cistus* hybrids. Recently TISCHLER (46, 48, 50) observed also the same phenomenon in *Cytisus Adami*, *Ribes Gordonianum*, and *Syringa* species. In *Cytisus Adami*, though good pollen-grains are produced, it is, as is well known, not fertile and it is found that the sterility is due chiefly to the early disintegration of the embryo-sac; the normal embryo-sac is, however, sometimes produced exceptionally. In sterile hybrid *Ribes Gordonianum*, Lem. (*R. aureum*  $\times$  *R. sanguineum*) the embryo-sac is degenerated early during its development, though a normal embryo-sac with the egg apparatus, polar nuclei and antipodal cells may be formed occasionally. In *Syringa chinensis* (*S. vulgaris*  $\times$  *S. persica*) and in *S. persica*, nearly the same mode of development takes place. In sterile hybrid *Drosera longifolia*, var. *obovata*, ROSENBERG (38,39) found that the development of the embryo-sac usually stops in the binucleated stage. Recently MÜCKE (32) has studied *Acorus Calamus*, which is always sterile in Europe, and found that both pollen-grains and embryo-sacs are degenerated in early stages of development.

The frequent disintegration of the embryo-sac as in *Citrus*, as described here, seems to occur occasionally. HEGELMAIER (22) announced that in certain *Linaceae* some of the embryo-sacs go into degeneration, while others are formed normally. GEERTS (19) also described in his paper that the "partielle Sterilität" of the embryo-sac is most commonly seen in the *Onagraceae*. FAMILLER (13) has stated that though the same takes place in the embryo-sacs of some *Caprifoliaceae*, *Umbelliferae*, and *Valerianaceae*, the mode of their degeneration is different from that above mentioned. According to him, the embryo-sac is generally well formed, but the integuments are very feebly developed, so he thinks it to be probable that here the sterility is due to the lack of sufficient nutrition.

In *Citrus* I have examined also the vegetative tissue of ovules, e.g., the nucellus, the inner and outer integuments, the chalaza, and the funiculus, but I could not find there any deviation between the sterile and the normal fertile species. The vegetative tissues are always well developed. The inner integument is three-layered, and the outer four layers thick in many cases (Fig. 70). In "Unshu" and "Washington Navel Orange" the nucellus is



always well developed, and consists of a number of large cells containing large vacuoles, even when the embryo-sac itself has been degenerated in an earlier stage. In the light of these facts, it may be inferred that the degeneration is not due merely to the lack of nutrition in that part, but that it must be due to some more deep-rooted cause.

### Germination of Pollen-grains and some Field Experiments.

Though, as above mentioned, several irregularities may take place in the later stages of the pollen development, yet some pollen-grains seem to be normally developed. So I have undertaken experiments on their germinative power in cane-sugar solutions of various concentrations. Pollen-grains of many *Citrus* varieties, e.g. "Natsu-mikan," "Kishu-mikan," "Asahi," and a few others, germinate easily in the 7--10% cane-sugar solution after 12 or 24 hours. Of the "Unshu," however, even good grains germinate very rarely, while many do not germinate at all even after 24 hours or more in solutions of various concentration. KUMAGAI (29) describes that there are only few functional pollen-grains in "Unshu"; IKEDA (24) mentioned that there is scarcely any good pollen-grain.

According to my present investigation, the number of good functional grains appears to differ, to some extent, in different individuals, for in a certain individual it was found indeed that 5% or even more of pollen-grains possess germinating power. A similar fact was also observed by TISCHLER (50). In sterile *Potentilla* hybrid, some pollen-grains are produced in a normal way and having two nuclei, generative and vegetative, are easily induced to artificial germination. In a sterile *Mirabilis* hybrid some pollen grains are normally produced as in *Potentilla*; and with respect to their germinating power, he says, "Ob diese Pollenkörner noch auskeimen können, vermag ich leider nicht zu sagen. Professor CORRENS schrieb mir, dass es weder ihm noch auch andern überhaupt gelungen sei, *Mirabilis*-Pollen künstlich zum Keimen zu bringen." He has also studied sterile

banana-pollen (51) and observed that the pollen-grains produced by the irregular division may sometimes germinate normally.

From their respective field experiments KUMAGAI (29) and IKEDA (24) conclude that the seeds of "Unshu" and "Washington Navel Orange" are easily produced, if pollinated with other fertile species, e.g. "Asahi," "Natsu-mikan," "Kunenbo," and many others. I have pollinated artificially "Unshu" with "Natsu-mikan" and "Kishu-mikan," etc. The fruits were examined in autumn and I found that the seeds of each fruit are very few in number, commonly about from one to five or rarely more. The fruit of "Navel Orange" was not examined.

In several districts, where "Unshu" and "Washington Navel Orange" as well as fertile varieties producing normal pollen grains are cultivated near together, the fact is well known—and I can also fully confirm it myself—that fruits of the former are very few-seeded, though we see in every orchard innumerable bees and other insects, which are busily engaged in visiting flowers.

The fact accords well with the results of the above investigation and is explainable by the above mentioned partial sterility of the embryo-sacs, which occurs in "Unshu" and "Washington Navel Orange." The details of these field experiments I hope to publish in a future paper, for I am now just engaged in these experiments.

### Discussion.

As above mentioned, the sterility of "Unshu" and "Washington Navel Orange" is chiefly due to the absence or sterility of the pollen-grains, but partly to the frequent disintegration of the embryo-sac. We ask then necessarily why such irregularities and abnormalities have been induced to occur? Before we proceed further, I will briefly mention the possible causes of sterility and of irregularities of germ-cells in plants, as discussed by many authors.

1. That hybridization is frequently the cause of sterility has been well known for a long time, and the fact has been observed by many authors as already mentioned.

2. Some authors have expressed the opinion that the sterility of plants is due sometimes to the influence of unfavorable climate. For example, MÜCKE (32), in his study of *Acorus Calamus*, which is always sterile in a certain district of Europe, found that pollen-grains and embryo-sacs have been degenerated in an earlier stage of their development and concluded that their sterility is due to the climate being unfavorable for the plant. Such cases seem to be frequently met with in newly introduced plants.

3. Irregularity of pollen-grains may occur from long or careful culture (9). WILLE (55), studying the pollen development in Angiosperms, has found that irregularities in the nuclear division, especially the appearance of supernumerary nuclei in the tetrad division, occurs chiefly in cultivated plants. TISCHLER (50) also made an interesting experiment in order to decide whether the cultivation under different circumstances can produce any irregularity in pollen development. The objects of his study were *Potentilla Tabernaemontani*, *P. rubens*, and a hybrid between these two parents (this hybrid is perfectly sterile). Both parents, though they produce in nature many irregularly shaped sterile pollen-grains, are yet fertile. He put them in a green-house in November, keeping them dark, wet and warm. Their pollen-grains produced under this treatment showed clearly more irregularities than in nature and the number of "taub" pollen-grains was much greater. Moreover by this treatment *P. rubens* was made to be perfectly sterile. A similar experiment was carried on by WULF (56) in certain pure *Potentilla* species and he found nearly the same phenomenon.

4. It is also probable that the irregularities and the sterility of pollen-grains are sometimes due to mutation, as fully discussed by GATES (17), TISCHLER (50), GEERTS (19), and others.

5. That these irregularities occur in many parthenogenetic plants has been announced by JUEL in *Antennaria*, MURBECK (36) in *Alchemilla*, SHIBATA and MIYAKE (41) in *Houttuynia cordata*.

In *Citrus* varieties, whether they are due simply to long cultivation or else to hybridization is now hardly possible to decide, for we have no reliable description about their origin. But that these *Citrus* varieties have long been under careful cultivation, together with the fact that cultivated



plants are very commonly hybridized spontaneously (vicinism), leads us to the inference that in all probability these plants might be hybrids.

Then the question naturally arises, why hybrids and their germ-cells are so frequently sterile? This question has been already discussed by numerous authors. This important problem will be decided only after a careful examination and comparison of a great many forms with similar irregularities. So I will not enter here into the discussion of this difficult problem.

### Summary.

1. The tapetum of the anther of *Citrus* seems to be derived from the original sporogenous tissue.

2. The first nuclear division of the pollen-mother-cell is reducing and heterotypic, while the second is equal and homotypic.

3. The number of chromosomes of "Unshu" is probably eight for the gametophyte, sixteen for the sporophyte.

4. The megaspore-mother-cell and tapetal cell are derived from a single hypodermal archesporial cell.

5. More than one megaspore-mother-cells are sometimes present in *Citrus*.

6. The first nuclear division of the megaspore-mother-cell is the reducing one.

7. A row of four megaspores are formed by two successive divisions of the megaspore-mother-cell.

8. The outer or micropylar three megaspores disintegrate, whereas the innermost or chalazal megaspore gives rise to a normal embryo-sac.

9. In *C. trifoliata*, fertilization appears to take place about four weeks after pollination.

10. In *C. trifoliata*, the primary endosperm nucleus may divide immediately after fertilization, and earlier than the oospore nucleus.

11. In *C. trifoliata*, the first nuclear division of the oospore appears to take place nearly three or four weeks after fertilization.

12. Phenomena of polyembryony are to be seen commonly in *C.*



*trifoliata*; embryos are then derived from nucellar cells, except one from the ovum.

13. The occurrence of the so-called "navel" at the top of the fruit of "Washington Navel Orange" is due to the multiplication of loculi and carpels, and to the protrusion of these new carpels beyond the top of the fruit.

14. The production of two or more seedlings from a single seed of *Citrus trifoliata* is not rare and in many cases these seedlings may grow to perfect plants.

15. In one or more loculi of the anther of "Unshu" the formation of sporogenous cells may sometimes fail and the number of pollen-mother-cells in a single loculus is very variable.

16. In "Unshu" the disintegration of the pollen-mother-cell and tapetum may take place as early as its resting stage, but the great majority of them passes through usual meiotic divisions and produces pollen-grains.

17. Pollen-grains of "Unshu" are mostly irregularly shaped and sterile.

18. Disintegration of the pollen-mother-cells and tapetum in "Washington Navel Orange" occurs as early as the sporogenous stage, and a great majority of them are degenerated and disappear in the stage of resting nucleus and never proceed to further development.

19. No pollen-grains are found in the anthers of "Washington Navel Orange" in its flowering period.

20. Disintegration of the embryo-sacs sometimes takes place in "Unshu" and "Washington Navel Orange," and it may occur in an earlier stage of their development, but their great majority seems to persist till a row of four megaspores is produced and then goes to disintegration.

21. As some normal embryo-sacs are produced in "Unshu" and "Washington Navel Orange," they may easily produce a few seeds, if pollinated with good pollen-grains of certain fertile species of *Citrus*. The small number of seeds in many cases is evidently due to the frequent disintegration of the embryo-sacs.

22. Seedless fruits of these two *Citrus* are produced, chiefly owing to the lack or sterility of pollen-grains, and partly to the frequent disintegration of the embryo-sacs.

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## EXPLANATION OF PLATES.

All figures were drawn with the aid of a camera lucida, except Figs. 86, 87, and 90. The abbreviations here employed are as follows; *a*, anther; *ac*, archesporial cell; *an*, antipodal cell; *c*, carpel; *e*, embryo; *es*, embryo-sac; *en*, endosperm nucleus; *ii*, inner integument; *l*, locus; *m*, megaspore; *mm*, megaspore-mother-cell; *ml*, middle layer; *n*, nucellus; *o*, ovary; *ci*, outer integument; *ol*, ovule; *oo*, oosphere; *p*, petal; *pl*, placenta; *pm*, pollen-mother-cell; *pn*, polar nucleus; *pt*, pollen tube; *s*, stamen; *sy*, synergid; *t*, tapetal cell.

## PLATE VIII.

Figs. 1, 2, 22—36, "Washington Navel Orange"; Figs. 3—21, "Unshu."

Fig. 1. Longitudinal section passing through the centre of a young bud, showing that the carpellary cavity is not yet closed above. The beginnings of petals, stamens, and carpellary leaves are visible.  $\times 21$ .

Fig. 2. Transverse section of a young bud, showing young sepals, petals, stamens, and carpellary leaves.  $\times 21$ .

Fig. 3. Longitudinal section passing through the centre of an older bud.  $\times 21$ .

Fig. 4. Transverse section of bud at the top of the carpellary leaves.  $\times 21$ .

Fig. 5. The same, at the middle of the carpellary leaves.  $\times 21$ .

Fig. 6. The same, at the base of the carpellary leaves.  $\times 21$ .

Fig. 7. Longitudinal section of older bud than that in Figs. 4, 5, and 6, passing through the centre.  $\times 21$ .

Fig. 8. Longitudinal section of a pistil, showing small protuberances (young ovules),  $\times 30$ .

Figs. 9-14. Six consecutive transverse sections at different heights of a pistil from the top to the base, showing the primordia of ovules.  $\times 30$ .

Fig. 15. Longitudinal section of an older pistil, showing young ovules.  $\times 30$ .

Figs. 16-20. Longitudinal sections of loculi, showing several stages of development of ovule.  $\times 45$ .

Fig. 21. Cross section of an ovary showing ovules.  $\times 21$ .

Fig. 22. Longitudinal section of a young ovary.  $\times 21$ .

Fig. 23. The same in more advanced stage.  $\times 21$ .

Figs. 24-29. Six consecutive cross sections at the different heights of a single pistil from top to base.  $\times 30$ .

Fig. 30. Longitudinal section of an older ovary, showing placentae and ovules.  $\times 21$ .

Figs. 31-34. Four consecutive cross sections of a single ovary, showing development of new irregular loculi at the upper portion of an ovary.  $\times 21$ .

Fig. 35. A portion of transverse section of an older ovary, showing new loculi, placentae, and ovules.  $\times 21$ .

Fig. 36. A portion of longitudinal section of an ovary, showing placentae and ovules.  $\times 21$ .

# PLATE IX.

Figs. 37-64, Figs. 66-71, "Unshu"; Fig. 65, trifoliate orange.

Fig. 37. Transverse section of a young anther, showing two microsporangia only.  $\times 190$ .

Fig. 38. A portion of transverse section of young anther, showing one microsporangium.  $\times 370$ .

Fig. 39. Transverse section of microsporangium in later stage, showing the differentiation of pollen-mother-cells and tapetum.  $\times 370$ .

Fig. 40. A pollen-mother-cell with a resting nucleus.  $\times 1190$ .

Fig. 41. The same, with the nucleus in synapsis.  $\times 1190$ .

Fig. 42. The same, with the nucleus in spirem stage.  $\times 1190$ .

Fig. 43. The same, showing the splitting of spirem thread.  $\times 1190$ .

Fig. 44. The same, more advanced stage.  $\times 1190$ .

Fig. 45, a, b. A single pollen-mother-cell cut into two serial sections, showing eight chromosomes.  $\times 1190$ .

Fig. 46. A pollen-mother-cell showing tripolar spindle.  $\times 1190$ .

Fig. 47. The same, in the prophase of the first mitosis.  $\times 1190$ .

Fig. 48. The same, polar view of chromosomes forming the nuclear plates.  $\times 1190$ .

Fig. 49. The same, in the late anaphase.  $\times 1190$ .

Fig. 50. The same, in the telophase of the first mitosis.  $\times 1190$ .

Fig. 51. The same, showing the prophase of the second mitosis.  $\times 1190$ .

Fig. 52. The same, telophase of the second mitosis.  $\times 1190$ .

Fig. 53. Tetrad.  $\times 1190$ .

Fig. 54. A pollen grain with one nucleus.  $\times 1190$ .

Fig. 55. A pollen-grain with two nuclei, generative and vegetative.  $\times 1190$ .

Fig. 56. A very young ovule showing a single hypodermal archesporial cell.  $\times 370$ .

Fig. 57. A young ovule, showing a megaspore-mother-cell, two tapetal cells, inner and outer integuments, and nucellus.  $\times 370$ .

Fig. 58. A megaspore-mother-cell in resting stage with two tapetal cells.  $\times 1190$ .

Fig. 59. The same, at later stage, showing three tapetal cells.  $\times 1190$ .

Fig. 60. An older ovule than that in Fig. 57.  $\times 370$ .

Fig. 61. A megaspore-mother-cell with nucleus in synapsis.  $\times 1190$ .

Fig. 62. Two megaspore-mother-cells in an ovule.  $\times 1190$ .

Fig. 63. A megaspore-mother-cell in later stage.  $\times 1190$ .

Fig. 64. The same in the early anaphase of the first mitosis.  $\times 1190$ .

- Fig. 65. The same in the anaphase of first mitosis.  $\times 1190$ .  
Fig. 66. A row of four megaspores.  $\times 1190$ .  
Fig. 67. Four megaspores: the upper three are degenerating and the fourth is functional.  $\times 1190$ .  
Fig. 68. The same.  $\times 1190$ .  
Fig. 69. Four megaspores: two in degeneration.  $\times 1190$ .  
Fig. 70. An older ovule showing megaspore, nucellus, and two integuments.  $\times 380$ .  
Fig. 71. More advanced megaspore or embryo-sac, showing vacuoles.  $\times 1190$ .

## PLATE X.

- Figs. 73-76, 86-89, "Unshu"; Figs. 72, 78-85, 90, trifoliate orange; Fig. 77, "Washington Navel Orange"
- Fig. 72. Two nucleated embryo-sac.  $\times 1190$ .  
Fig. 73. An ovule showing embryo-sac, nucellus, and inner integument.  $\times 370$ .  
Fig. 74. Details of embryo-sac of Fig. 73, with four nuclei.  $\times 1190$ .  
Fig. 75. Embryo-sac with eight nuclei.  $\times 1190$ .  
Fig. 76. A mature embryo-sac with egg-apparatus, pollar nuclei, and antipodal cells.  $\times 1190$ .  
Fig. 77. The same.  $\times 1190$ .  
Fig. 78. Ovule after fertilization, showing two integuments, nucellus, and embryo-sac.  $\times 54$ .  
Fig. 79. Details of the embryo-sac of Fig. 78, more magnified, showing fertilized egg, one synergid, pollen-tube, and endosperm nuclei.  $\times 550$ .  
Fig. 80. Micropylar portion of an embryo-sac, showing fertilized egg, pollen tube, and endosperm-nuclei, especially some large nucellar cells containing large nucleus and much cytoplasm.  $\times 370$ .  
Fig. 81. The same.  $\times 550$ .  
Fig. 82. Micropylar portion of an embryo-sac showing two-celled embryo and endosperm nuclei.  $\times 370$ .  
Fig. 83. An older ovule, showing embryo-sac, embryo, endosperm-nuclei, nucellus, and integuments.  $\times 40$ .  
Fig. 84. Upper portion of embryo-sac of Fig. 83 more magnified, showing six-celled embryo, endosperm nuclei, and nucellus.  $\times 370$ .  
Fig. 85. Upper portion of an embryo-sac, showing polyembryony.  $\times 370$ .  
Fig. 86. Cross section of a single loculus, showing ovule and small protuberances (future "juice-sacs").  $\times 6$ .  
Fig. 87. The same in later stage.  $\times 6$ .  
Fig. 88. Early stage of development of "juice-sacs,"  $\times 370$ .  
Fig. 89. The same in later stage.  $\times 198$ .  
Fig. 90. Cross section of a single loculus, showing ovule and young "juice-sacs."  $\times 5$ .

## PLATE XI.

Figs. 91-106, "Unshu"; Figs. 107-115, "Washington Navel Orange."

Fig. 91. Cross section of a young anther, only one microsporangium is visible.  $\times 190$ .

Fig. 92. Cross section of a single microsporangium, showing only one pollen-mother-cell in mitosis.  $\times 370$ .

Fig. 93. The same in a little later stage, showing irregular thick tapetum and a few pollen-grains.  $\times 370$ .

Fig. 94. The same in older stage, showing several irregular pollen-grains.  $\times 370$ .

Fig. 95, *a*, *b*. Tapetal cells with irregular aggregate of nuclei.  $\times 840$ .

Fig. 96. Cross section of a single microsporangium, showing degenerated pollen-mother-cells and tapetum.  $\times 370$ .

Fig. 97. The same.  $\times 370$ .

Fig. 98. The same in flowering time.  $\times 370$ .

Figs. 99, 100. Cross section of an anther showing irregularities of microsporangium in the flowering period.  $\times 67$ .

Figs. 101-105. The same.  $\times 40$ .

Fig. 106, *a*, *b*, *c*, *d*. Irregular pollen-grains.  $\times 1190$ .

Fig. 107. A portion of a young anther, showing one microsporangium.  $\times 370$ .

Fig. 108. Cross section of a microsporangium, showing sporogenous cells with large vacuoles.  $\times 370$ .

Fig. 109. The same, showing tapetum and mother-cells.  $\times 370$ .

Fig. 110. The same in later stage, showing the degeneration of pollen-mother-cells and tapetum.  $\times 370$ .

Figs. 111, 112. Transverse section of a single microsporangium, showing the disintegration of mother cells and tapetum.  $\times 370$ .

Fig. 113. Portion of the cross section of an anther, showing degenerated pollen-mother-cells and tapetum, which remain as a ring-shaped body.  $\times 144$ .

Fig. 114. Cross section of anther in flowering time.  $\times 40$ .

Fig. 115. *a*, *b*, *c*. Pollen-mother-cells with a few nuclei.  $\times 1190$ .

## PLATE XII.

Figs. 116-120, "Unshu"; Figs. 121-127, "Washington Navel Orange."

Fig. 116. Small and feeble megaspore, scarcely distinguishable from the surrounding cells.  $\times 1190$ .

Fig. 117. The same in later blossoming period.  $\times 1190$ .

Figs. 118, 119. Degenerated embryo-sac.  $\times 1190$ .

Fig. 120. The same with nucellus tissue.  $\times 550$ .



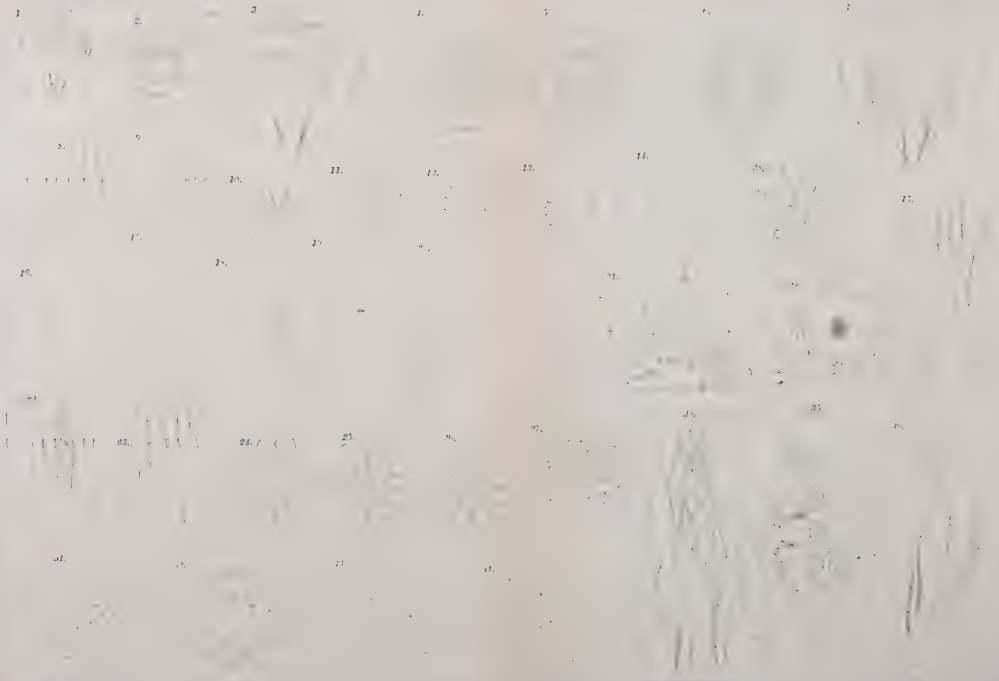
- Fig. 121. Long and narrow irregular megaspore-mother-cell half degenerated.  $\times 1190$ .  
Fig. 122. A row of four megaspores, already degenerated.  $\times 1190$ .  
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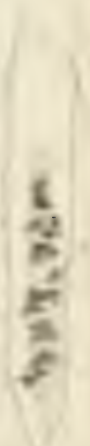
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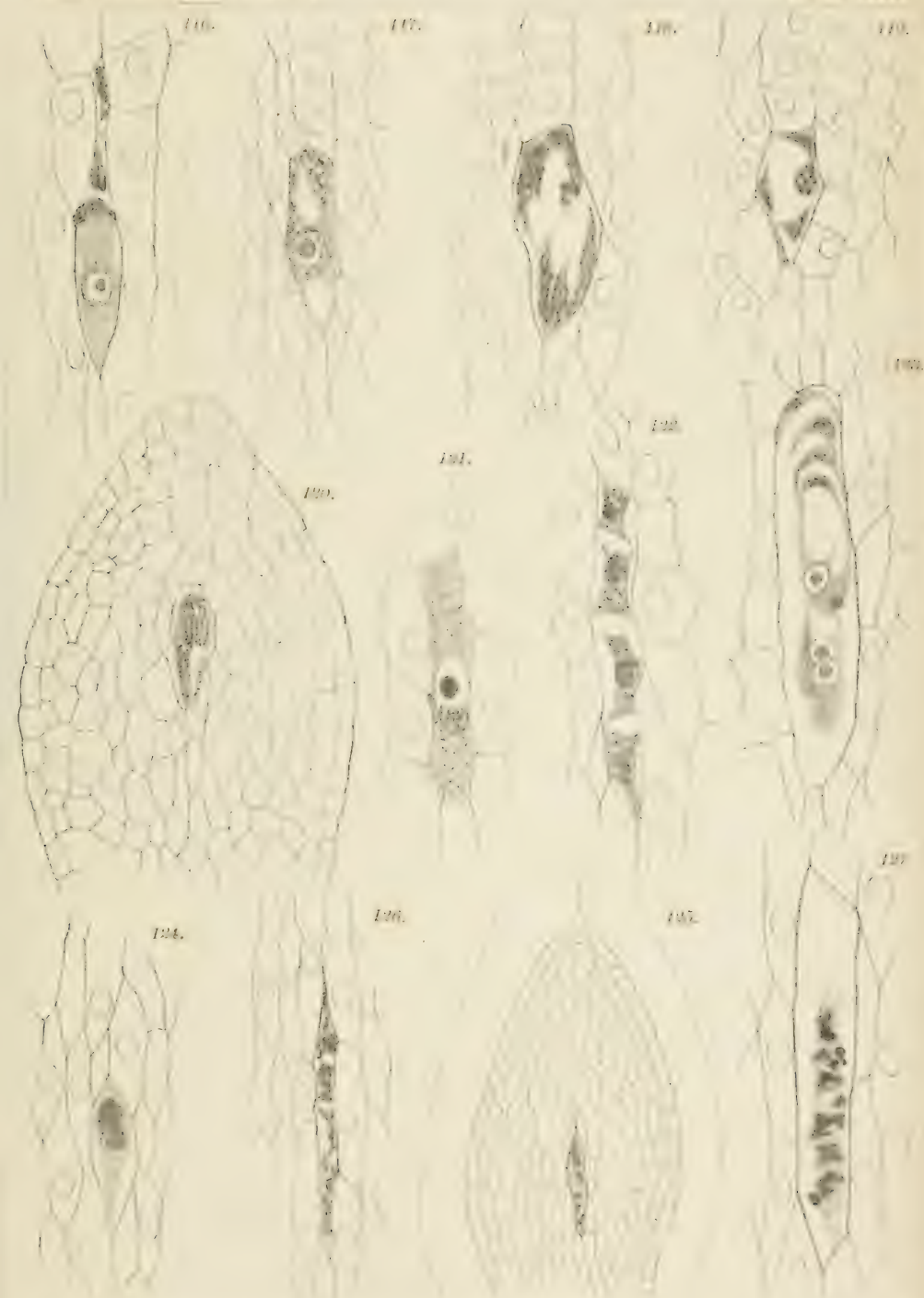








116<sup>5</sup>







# The Life-History of *Panorpa klugi* M'Lachlan.

BY

**Tsunekata Miyaké.**

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With Plates XIII and XIV.

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## I. Introduction.

The complete life-history of the order Mecoptera is scarcely known. Though MACQUART,<sup>1</sup> STEIN<sup>2</sup> and possibly some others have thrown light on certain stages of the life-history of the genus *Panorpa* in a fragmentary way, the only entomologist who has observed the complete life-history of Panorpid seems to be BRAUER<sup>3</sup> who published his results in 1863. He worked on the European species belonging to the genus *Panorpa*.<sup>4</sup> In 1895, an American author FELT<sup>5</sup> has published his observations on the American species *Panorpa rufescens* Rambur, but they are confined to larval life, and his remarks on pupal stage are simply quotations from BRAUER. After several failures I have recently been able to succeed in obtaining all the stages of the Japanese species *Panorpa klugi* M'Lach., and I propose to describe my results in this paper. So far as I know this is the first published report on the life-history of a Japanese species of this genus and as our knowledge of the life-history of this order is so unsatisfactory this contribution should be not only of local but also of general interest. Moreover our interest increases when we consider that *Panorpa klugi* M'Lach. together with many other Japanese species has recently been made a separate genus, by ENDERLEIN,<sup>6</sup> under the name of *Aulops*, and a study of the life-history of a representative of the new genus would help us in judging of its taxonomic value, and if the genus found to be valid, in throwing light on the metamorphosis of the new genus. Besides I have found out that the spiracles of Panorpid larvae undergo certain structural modifications with each moult, so that we can roughly determine the different stages by observing the spiracles.

As my materials were very scarce for certain stages, especially the pupal, the conclusions referring to them should be received with a certain

1. MACQUART: Ann. d. Science Naturell., Tom., 22, p. 463—465 (1831). (After BRAUER).
2. STEIN: WIEGMANN'S Archiv 1838, p. 330, tab. 7. (After BRAUER).
3. BRAUER: Verhandl. d. zool-bot. Gesellsch., Bd. XIII, p. 307—324 (1863).
4. He wrote the life-history collectively, though he described the larvae of *Panorpa variabilis*, *P. montana* and *P. communis* respectively.
5. FELT: Tenth Report. State, N. Y., p. 463—480 (1895).
6. ENDERLEIN: Zool. Anz., Bd. XXXV, p. 390 (1910).

reserve, and therefore I hope the reader will look upon this report as a preliminary one.

Lastly the author wishes to express his hearty thanks to Professor SASAKI, to whom he is much indebted for many valuable advices received during the study. To Professor ISHIKAWA he is also under deep obligation for his several kind suggestions. In no less degree his thanks are due to Professor GOTO for his favour in looking through the manuscript.

## II. Methods.

For observations I made occasional visits to some fixed spots in various localities, such as Inokashira, Takao-yama, Hakone, etc., where *Panorpa klugi* as well as many other species are very common. For closer observations I placed a number of *Panorpa* in breeding-cages, which were 410 mm. in height and 250 mm. on the sides, with sliding doors of glass plate in front and behind, and with apertures covered with wire-screen on the other two sides; the top side had a movable cover of wire-screen and at the bottom was placed a drawer lined with zinc plate. Into each cage I put a potted plant of various kinds in moist sand. In some cases however I filled the bottom of cages with moist sand in which I set some plants. The latter method however did not give good results, as the insects could not find so many sheltering places as in potted plants. It was necessary that not only the sand in the pot, but also the whole interior of the cage should always contain certain degree of moisture. I therefore poured every day some drops of water on the upper wire-screen through which it passed into the cage in the form of vapour. The insects seemed to relish it very much, as some of them were seen to be eagerly sucking at the drops. However the moisture should not be present in excess, as it impedes the movement of the insects. As for the food, I first gave, following BRAUER and FELT, pieces of flesh (beef, pork and fish were tried), but the results were not satisfactory, and subsequently I found that wounded or dead insects were accepted and left nothing to be desired. For this purpose silk-worms and their chrysalises were commonly used merely because they were very easily obtainable. When the eggs were deposited each lot was put into a

PETRI dish filled with moist sand. After taking this step great care is still necessary, as the eggs are subject to the attacks of some entomophthoreous fungi, which cause the eggs to swell and make the shell so delicate that the eggs burst at a slight touch; and though such eggs may be kept safely through the larvae usually do not hatch out. The hatched larvae were kept either in dishes or cages and were fed also with wounded silk-worms, the proper moisture of the sand being always attended to. During larval life many are killed by parasitic nematodes. To prevent this the sand was disinfected with hot-water but the result was not thoroughly effective. Besides the nematodes there are many coleopterous enemies which are to be carefully guarded against. When the larvae are full grown and begin to form their cells, they usually burrow deeper in the sand or wander about at the surface, possibly in order to avoid too much moisture. If at this time the usual moisture is still given the larvae will perish, and I repeatedly failed at this juncture. We have therefore to take means to diminish the moisture or to remove the larvae into vessels with dried sand. But a very slight degree of moisture must still be kept up, as complete desiccation would kill the larvae. After pupation great care is necessary to leave the pupae in as tranquil and natural a condition as possible. Even when all the precautions have been taken a fair proportion will fall prey to the various enemies.

### III. Habits of the Adult Insect.

The adults are usually found in damp shady places where the ground is covered with bushes of grass. The males may be seen resting on a leaf, bending up the last three abdominal segments in such a way as to make the terminal forceps very conspicuous to sight. The females are also found along with them, the abdomen being extended straight, and commonly lie nearer the ground than the males. In both sexes, when excited, as for fighting or copulation, or else watching for prey or preparing for flight, the wings are slowly elevated and depressed alternately. Though these scorpion-flies may look restless, yet they are in reality rather dull insects and one may easily catch them with a net or even by fingers. When held between



the fingers they occasionally eject a brownish fluid with offensive odour, just like grass-hoppers. This may probably have some protective meaning. The flights are usually taken by short distances just like those of Agrionid dragon-flies. In nature the insect is often attacked by species of ectoparasitic mites which are reddish in colour and rather large and conspicuous in appearance.

**a. On some economic points:—** Whether *Panorpa* preys on living animals or not, in other words, whether it is useful or not, has so far as I know not yet been determined for any species. KIRBY and SPENCE in their Entomology vol. ii, p. 253 (1828)\* record that *Panorpa communis* preys on living insects, adding "LYONNET saw one attack a dragon-fly of ten times its own bigness, bring it to the ground, pierce it repeatedly with its proboscis." FELT quotes another example from Prof. DAVIS of the Michigan Agricultural College, who writes "very common in the fields and noticed to attack the cotton-worm." He however remarks as follows:—"It is possible that *Panorpa* does attack and kill its own prey, but there appears to be no undoubted proof of this at present, unless the account of KIRBY and SPENCE is credited—it does not seem possible that it could be true of our species at least. .... Our species were under close observation, indoors and outdoors, for six weeks, yet they were not yet seen to touch a living, uninjured animal of any kind and they were seen a number of times in nature feeding upon partially decayed insects: neither the mandibles nor the maxillae of this insect are well adapted to piercing." POULTON in 'Transaction of Entomological Society of London, 1906,' and LUCAS in 'Entomologist, 1910' record many European species feeding on insects, but whether they were uninjured living insects or not does not seem to have been ascertained. In Japan, Mr. OXUKI of the Entomological Division of the Imperial Agricultural Experiment Station describes in his "Jitsuyo Konchūgaku" (Practical Entomology), p. 35 (1903), that the scorpion-fly preys on living insects. Professor MATSUMURA of the Tohoku University mentions the same fact in his "Ekichū-mokuroku" (Catalogue of Beneficial Insects), p. 42 (1908). For my own part, I saw on June 19th a female attacked a larva of its own. The larva had suffered no

\* I follow FELT's quotation; in the edition of 1873 in my hand the passage cannot be found on the page cited.

external injury nor was it otherwise unhealthy as far as I could observe, although on this latter point we cannot have any positive assurance. After some minutes I separated the female from the larva, and I could assure myself that the larva was still in a very vigorous state. However it is surely a difficult problem to determine whether the prey on which *Panorpa* was feeding had been in perfect health or whether *Panorpa* feeds only on injured or dead insects, since the activity of different insect species is so different that the healthy individuals of some inactive species are often as quiet as the dead ones of other. To throw some light on the question, I have made many experiments by confining uninjured maggots, caterpillars (Noctuids, Geometers, silk-worms, etc.), moths and flies in the cages containing a number of scorpion-flies; yet I have never observed the latter injure or touch the former, although the scorpion-flies must in some cases at least have been in a starved condition. On the contrary, if any of these food insects were injured or dead, more especially if the body fluid had more or less flowed out, notwithstanding that the animals were still in an active condition, the scorpion-flies would instantly fall on them and begin to eat, heedless of the movements which the prey may make. For these facts we may safely conclude, with FLET, that though *Panorpa* may not be entirely exempt from attacking living animals, still its usual food consists of dead or injured or sometimes even partially decayed insects. And it is an ordinary thing to see scorpion-flies feeding on their dead comrades. As the same may be observed during larval life we may conclude that the scorpion-flies are economically of much less value than one might imagine, and that their possible use may be that of scavengers, though on this point also their usefulness appears to be very limited.

On the other hand I sometimes saw (e. g. on June 6th, beforenoon) a female scorpion-fly sucking a petal of a sweet-william catchfly (*Silene Armeria* L.) that was potted in the cage. The entire tissue of the part sucked was destroyed so that afterward the petal dropped down, the margin of the injured portion showing a bluish black (see Pl. XIV, fig. 8+). In this way all the petals of a cage were attacked in a few days. There is no doubt that *Panorpa* feeds occasionally on vegetable matter and hence that it may sometimes be injurious to plants.

**b. Copulation:**—Copulation takes place very often. In approaching a female the male flutters its wings, and is, of course, usually responded to by the former, and stretching straight its abdomen the male seizes with chelae the abdomen of the female on the dorsal side or sometimes on the ventral side, and slides the chelae backward until the genitalia of the female are reached. During the copulation the two insects remain attached by the hind ends while the bodies diverge in the form of a  $\Delta$ . The attitude of the female during this process is perfectly natural with its wings folded, and its abdomen straight, while that of the male is very unnatural, and the body axis is strongly curved in the form of an  $f$ . Copulation lasts from a quarter of an hour to often over an hour. Some examples are as follows:—

May 28/'11	A.M.	11.30—12.00	.....	30 minutes
June 6/'11	A.M.	9.05—10.44	.....	1 hour 39 minutes
„	P.M.	3.46— 5.20	.....	1 hour 34 minutes

The male after finishing a copulation sometimes proceeds to effect a second one with another female found near by. I saw on Oct. 10th '11, one and the same male copulating twice, the first lasting for about 15 minutes and the second immediately afterward with another female for 40 minutes.

One male is usually surrounded by two or three females, which seem to the observer to be coquetting with the male. I saw on June 5th a pair in copulation besides two females. At last one of the two (I think the stronger one) began to disturb the pair in copulation using its long beak as a weapon and succeeded finally in separating them. The successful rival then effected a pairing on the spot.

It is very interesting that, though the female is very eager for pairing, she is commonly seen to take food during copulation (as it frequently takes place within reach of food) as if she were indifferent to it, while the male seems to be entirely occupied with it.

**c. Longevity:**—The life of the adult insect lasts rather long. Even in confinement in the cage the female lives usually over a month. In the open field therefore she should live still longer. Speaking generally the male enjoys a shorter life than the female. The following are my observations in the cage.



## First brood

Number of individuals.	Date of capture.	Date of death.	Days of existence.
♂ .....	May 22/'11	June 5	15 days
♂ .....	"	June 6	16 "
2♀ .....	"	July 3	43 "
2♀ ..	"	July 7	47 "
2♀ .....	"	July 8	48 "
2♀ .....	June 1/'11	July 3	33 "
♀ .....	June 9/'11	July 10	31 "

## Second brood

♂ .....	Sept. 15/'11	Sept. 28	14 days
♂ .....	"	Oct. 11	26 "
♂ .....	"	Oct. 12	27 "
2♀ .....	"	Oct. 19	34 "
♀ .....	"	Oct. 25	40 "
♀ .....	"	Oct. 27	42 "

Many other observations were incidentally made during the investigation, but exact records were not kept.

**d. Egg-laying:**—The eggs are laid some days after copulation. Preliminary to oviposition the female explores every crevice in the ground, stretching its abdomen to full length. I made many artificial crevices in the sand to allure the females to lay eggs in them, but none of them was utilised, though every crevice was repeatedly examined by the females. Finally a mass of yellowish white eggs was laid in a slit between the pot and the bottom of the cage, in crevices of the sand, and corners of the cage, as also on the surface of the sand. The eggs more or less adhere together owing to the presence of some viscid fluid on their surface. The number of eggs in a batch is quite inconstant and not as GRABER observed, "nicht zahlreichen (höchstens 12)," or as FELT states, "twenty-four to twenty-nine being the number." My observations on the Japanese species are as follows:



First brood			Second brood		
Date		Number	Date		Number
May	31/'11	.... 66*	Sept.	25/'11	.... 27
June	4	.... 21*	Sept.	27	.... 30
June	12	.... 11	"		.... 13
"		.... 32	Oct.	3	.... 24
June	14	.... 53 (or 54?)	"		.... 20
"		.... 85	Oct.	20	.... 35
"		.... 18	"		.... 6
June	17	.... 96 (or 97?)	"		.... 7
June	19	.... 68	"		.... 30
"		.... 18			
June	21	.... 9			
"		.... 10			

We thus see that in the species in question the number of the eggs varies from 6 to 97 in one lot, and is very different from what is known in European and American species. For oviposition sheltered places are usually preferred and direct sunshine is avoided. Exceptionally however the eggs may be laid on the surface of the sand or food insect. In either case the parent does not seem to provide for the food of the future larvae, as FELT observed.

#### IV. The Egg.

The egg (Pl. VIV, fig. 6) is oval and whitish or pale yellowish just after deposition; in a day or two it turns fuscous yellow, but sometimes remains whitish till the last stage. Length 0.90—0.97 mm.; width 0.59—0.75 mm. It is therefore larger than in European and American species since BRAUER writes about the former " $\frac{2}{3}$ " lang und  $\frac{1}{3}$ " breit," and FELT reports for the latter "long diameter .625 mm.; short diameter .6 mm." The chorion is covered with a network of dark fine depressions, the meshes of which are mostly hexagonal and rather delicate, since it is easily broken by accidental touching.

**a. Hatching:**—The egg usually hatches out on the eighth day after

\*They were laid by the same female.

deposition, for example, eggs laid on May 31st hatched on June 7th, and those on June 14th on June 21st. But this period is not absolutely fixed, and in some cases the larvae hatch out on the 6th, 7th or 8th day after deposition. Eggs deposited on the same day not infrequently hatch out on different days.

On the day of hatching the larva can be seen through the chorion, curled up within the egg shell, with the head at one end of the egg covering the abdominal end (Pl. XIV, fig. 7); and the eyes, mandibles, antennae and setae on the dorsal side can be distinctly recognized. Just before hatching the larva is seen moving its mandibles and often rotating itself within the chorion; but these movements do not seem to be directly concerned in the process of hatching out. The actual hatching is effected by the larva by simply pushing up the chorion at one pole of the egg with the frontal portion of its head and when the chorion breaks the larva crawls slowly out of the shell. I have repeatedly seen the hatching process going on and the method is always the same. Only in one case was the shell broken in the equatorial region and the larva came out with the middle dorsal side of its body foremost. After leaving the egg shell the larva remains motionless for a while.

## V. The Larva.

The larva just hatched is 3—6 mm. long, and is milky white with remarkably fulvous head and very beautiful pinkish eyes. It soon begins gradually to darken and after a few hours the head is testaceous, eyes dark pinkish and the body yellowish grey. The general appearance is figured in Pl. XIII, figs. 1 and 2. The head (Pl. XIII, figs. 2, 4) is rather large, with a few setae on the epicranium, and bears an elongated reddish piceous patch on the clypeus. The antenna (Pl. XIII, figs. 2, 4, 9) is very prominent and has four joints, of which the basal two are short, the third is short and obconical, while the fourth is long and slender and bears three or four short setae at the top. On the under side of the antenna near the apex of the third joint there are two groups of rather large cells (I could count in the inner group about 9, and in the outer group about 13 cells, admitting

however that the actual number may be one or two more) with conspicuously large nuclei, which constitute probably a sense organ. The eye (Pl. XIII, fig. 10) is large and is composed of twenty eight ocelli (in the American species studied by FELT there are "about twenty"). The mouth parts are of mandibulate type. The mandible (Pl. XIII, fig. 7) is piceous (deeper in colour toward the apex), stiff and pyramidal, with internally curved apex. Near the base it bears two teeth and near the apex, which forms a sharp tooth, there is another triangular tooth. On the outer edge of the mandible there are usually two setae of unequal size. The maxilla (Pl. XIII, figs. 4, 6) is of single piece and bears a large maxillary palpus. The latter is four-jointed, the basal three joints being cylindrical and subequal, while the last joint is twice as long as any one of preceding and of cylindrical form with round apex. The apex of the maxilla is in most specimens set off by a faint transverse line, and this apical region is lightly coloured and bears a number of hairs and a few setae, of which one is rather prominent. Next this region an inwardly pointed triangular part is present, which is rather deeper in colour and bears a few setae. This pointed part bears a horny dark-coloured small process which is directed forward (in some specimens often indistinct). The two regions may possibly represent the galea. These regions are followed by another lightly coloured region, which is sharply pointed toward the horny process just mentioned. On its inner edge there is a bundle of hairs. This is probably the lacinia, and is followed by the basal portion (corresponding to stipes and cardo) which is united with the labium. Of the labium (Pl. XIII, figs. 4, 8) the labial palpi are prominent, touching each other along the median line of the body. They are three-jointed, the last joint being so long as the other two joints taken together. The hypopharynx (Pl. XIII, fig. 5) is spatulate, and bears on the anterior margin four prominent setae. The head is connected by a very slightly-narrowed neck to the first body segment, which bears on the lateral side near the ventral surface a chitinous semicircular ridge. (See Pl. XIII, figs. 1, 3). The body segments are pale yellowish grey and bears fine fuscous spots; the intersegmental lines are rather obscure. The prothoracic shield is very prominent, divided by a white median line into two lateral parts, each with three prominent setae on the anterior margin



and two on the posterior; with spiracles of a peculiar structure to be described further on. The remaining body segments bear on the dorsum each an irregularly elliptical chitinous shield, which is rather insignificant on the 8th and 9th abdominal segments. On the second and third thoracic and sometimes also the following few segments this shield is traversed by a pale median line. Each shield bears typically a pair of larger, two of smaller and a fourth of still smaller setae. The large setae on the 1st—10th abdominal segments are pilose and annulated. The annulated setae on the 8th—10th are strikingly larger and are cylindrical in the basal portion, while the corresponding smaller setae are reduced to rudiments (see Pl. XIII, fig. 4). The last (10th) abdominal segment bears only a single median annulated seta (Pl. XIII, fig. 11). This segment bears on the ventral side the four-branched retractile 'anal fork' or 'Haltgabel' (Pl. XIV, fig. 1), which is stretched out when the substratum is wet, very probably, as GRABER has remarked, for the sake of holding the body tightly. Further each body segment bears typically 6 tubercles on each side bearing each a seta, except the largest one near the leg, on which there are two setae. On the first segment and the last three however these tubercles are more or less reduced in number (see Pl. XIII, fig. 1). The first to 8th abdominal segments bear spiracles of a peculiar shape, so that, with those of the prothoracic segment there are 9 pairs of spiracles. Each thoracic segment has a pair of cylindrical legs with four joints, which very probably represents the coxa, trochanter, femur and tarsus. Between the trochanter and femur, there is on the internoposterior side another small triangular plate, which, as far as I can see, cannot be referred to any of the recognized parts of the leg. The first to 8th abdominal segments are provided with a pair of rather small cylindrical prolegs, so that there are 11 pairs of legs in all (see Pl. XIII, fig. 1).

**a. The larva after first moult:**—The larva does not present any essential change after the first moult, only the annulated setae of the first to 7th abdominal segments are now reduced to mere rudiments (see Pl. XIII, fig. 13). The annulated setae of the 8th to last abdominal segments become comparatively small while the basal portions become relatively larger and occupy about one third of the whole length, whereas in the first stage



they were only one fifth of the latter (see Pl. VIII, fig. 12).

In more advanced stages no greater changes take place—only the head and body become darker and in later stages slightly tinged with rosy colour. The spiracles of the prothorax and abdomen undergo certain changes which are described under a separate heading. The larva becomes full grown in 15 days and the length of body finally reaches 10-16 mm. (See Pl. XIII, fig. 3).

**b. Number of moults:**—FELT recognized seven stages in *Panorpa rufescens*, by measuring the width of the head according to DYAR's rule. I have also tried the rule on the Japanese species. I picked out from the cages some larvae every day, killed them in warm water and measured them under a microscope. The results were not so regular and constant as were shown by FELT, but broadly speaking seven stages may also be recognized in the Japanese species. They are tabulated below and are compared with the results of FELT. My measurements were made only to  $\frac{1}{100}$  mm., as it appeared to me meaningless to carry them further.

	Measurements by FELT.	Measurements by me.	Length of body.	Age of larva.
I stage	0.5625 .....	{ 0.54 ..... 0.55 .....	3— 6 mm. "	birth day "
II stage	0.6625 .....	{ 0.69 .. ... 0.70 .....	? 4— 7 mm.	? 3—4 days
III stage	0.7750 .....	0.78 .....	5— 6 mm.	5—6 days
IV stage	0.9375 .....	0.87 .....	5— 7 mm.	?
V stage	1.0625 .....	1.08 .....	7—11 mm.	5—6 days
VI stage	1.3255 .....	{ 1.43 ..... 1.48 .....	12 mm. 14 mm.	? ?
VII stage	1.5000 .....	{ 1.55 .. 7 mm.; 1.60 ..... 1.65 .....	10—16 mm. 15—16 mm. 17 mm.	10 days 15 days 15 days

As seen from this table, though the figures obtained are not very constant they can be made to fit into FELT's schema. If this be right the Japanese species goes through seven moults within 15 days, resembling in this respect the American species which does the same within two weeks.

The objections to this conclusion are: (1) The figures for each stage do not increase in proportion, as for example the differences between the second and the third, and the third and fourth are very small compared with that between the fifth and sixth. (2) The difference between the smallest and greatest figures for the 7th stage is quite equal to that between the 6th and 7th. Therefore if we assume the differences between successive stages to be nearly constant, then we should have to recognize the 8th stage. But fortunately the maximum figure of the 7th stage above mentioned referred to a unique specimen, which must be considered as exceptional, since all the other specimens that had burrowed for pupation were of smaller size. (3) Examples of the second stage that I could obtain were very few (only three), although those of the next stage could be obtained in abundance. If this second stage be left out there would be only 6 stages in our species, unless we recognize in the above mentioned giant form a separate stage, which would give again seven stages in all. If we however recognize both the giant form and the second stage, then there would be 8 stages, which is however very questionable as a matter of fact.

**c. Changes of spiracles:**—Though the larva remains nearly constant after the first moult, except for size, there occur certain changes in the spiracles. And as we can recognize seven stages in them, the fact that the *Panorpa* larva undergoes seven moults becomes still more probable and at the same time we learn the new fact that the spiracles of *Panorpa* undergo definite changes in each stage.

Speaking generally the spiracle (Pl. XIV, figs. 11, 12) of the *Panorpa* larva is of a circular form, with a solid, dark-looking portion in the centre, around which a series of small oval apertures are radially arranged. Each aperture has a hard margin united centrally with the solid middle portion. These small apertures are the external openings of the spiracle. Under these apertures there lies a common spacious cavity, the external boundary of which is most probably indicated by the circular line just under the apertures. This cavity may internally open into a trachea, where a single elliptical hole (Pl. XIV, fig. 14) is found. The prothoracic spiracle is always larger than the others and has more apertures. In the abdominal spiracles the number of apertures is not strictly constant, those situated near the

end of the body having one or two less than the rest. In the first stage the prothoracic spiracle (Pl. XIV, fig. 9) has a diameter of 0.035 mm., and the middle portion is very small while the radially arranged apertures are very large and the septa very thin, that the entire spiracle appears as if to consist of single hole with radiating arms. Probably FELT was mistaken in this way. But a careful examination will reveal a number of radially placed septa separating the apparently single large hole into many apertures. The abdominal spiracle (Pl. XIV, fig. 10) is similarly constructed, but is smaller, the diameter being 0.03 mm. In the second and third stages (Pl. XIV, figs. 11, 12) the middle portion becomes larger and a very dark-looking elliptical body is present in the centre. The oval, elliptical or pear-shaped apertures become now far smaller and very distinct. In the later stages the middle portion becomes larger and larger and the apertures smaller and smaller. In the final stage (Pl. XIV, fig. 13) the entire spiracle becomes darker and the middle portion very large and a number of lightly coloured granules are found diffusely on it. The central dark-looking body acquires now the form of a **T** or of an irregular ellipse. The apertures become very small and elongated, and each shows slight constriction in the middle. The diameter of the thoracic spiracle measures in this stage 0.14 mm., and that of the abdominal 0.11 mm.

The transformation of the spiracles consists chiefly in the increase of the number of the radial apertures. However there are individual variations in each stage. The results of my observations are tabulated below.

	Width of head.	Number of apertures in the thoracic spiracle.	Number of apertures in the abdominal spiracle.*
I stage	0.54	9	7
	0.55	10	8
		11	8
II stage	0.69	17	11
III stage	0.78	19	12
		19	13
		20	14

\* I give the maximum number. In those near the end of the body the number may be one or two less than this.

	Width of head.	Number of apertures in the thoracic spiracle.	Number of apertures in the abdominal spiracle.
IV stage	0.87 .....	22	17
V stage	1.08 .....	27	18
VI stage	1.43 .....	{ 16†	11†
		{ 39	35
	1.48 .....	43	38
	1.43 .....	45	36
VII stage	1.55 .....	{ 41	36
		{ 47	35

As can be seen from this table, the apertures gradually increase in number with each moult, though there are some variations in each stage. And as the figures obtained can be divided into seven groups, the fact that *Panorpa* larva has seven stages, as ascertained by the breadth of the head receives an additional support. Unfortunately however in this case, just as in that of the breadth of the head, some ambiguities occur. That is, in the 6th stage we have four pairs of different figures one of which is so small that it may just as well be placed in the second stage, while the third and the prothoracic figure of the fourth are greater than the smaller pair of the 7th stage, so that only the second pair remains as properly belonging to this stage. The unusual smallness of the first pair of figures must be looked upon as an abnormality. Coming to the 7th stage one of the pairs of the figures is smaller than the greater one of the 6th stage, but the other is larger than any of the 6th. Besides I could count some 40 to 45 apertures on thoracic spiracles of some larva of the 7th stage, which I could not sacrifice for the sake of making a more exact count. For the same reason the exact number of spiracular apertures could not be ascertained for the giant specimen already mentioned, which must have possessed nearly 45 openings.

**d. Habits of larva:**—The larva is not very active; some time after leaving the egg it begins slowly to wander about, possibly in order to seek its food. It searches for something now and then, stopping here and there,

† This is very probably abnormal.



holding its head and antennae erected. However unless it happened to hatch out upon a food insect it usually does not get its prey directly. I have seen many larvae walking toward a quite different direction from the food, although the latter was placed apparently near enough to excite their sense organ. Wandering in this way the larva burrows into a crevice or sand if the latter is soft enough. The depth to which it burrows is quite variable, in some cases just below the surface and in some 40 mm. or more depth. One end of the burrow usually leads just to the edge or the under-side of a piece of food. Hiding itself in the burrow the larva reveals its head in the opening and takes its food. If some slight disturbance occurs it withdraws the head and hides itself in the burrow. Sometimes however it emerges entirely from the burrow and takes food on the open surface. I have given the larvae pieces of beef, fish and some injured insects, especially caterpillars and chrysalises, and the last seemed most acceptable. When an injured insect was given its cuticular part only was left on the next day, the contents having been entirely eaten up. Thus the food of the larva does not differ materially from that of imago, but whether it feeds on living uninjured insects is as much a question as in the case of the imago. So far as I have observed, uninjured caterpillars and insects put in the same cage with *Panorpa* larvae are never attacked by the latter, possibly because these are less active than the former. On this point FELT's observation differs slightly from that of mine, as he says:—"In the larval state they (*Panorpa*) are most probably predaceous and may aid in keeping some of the smaller injurious insect in check. In the imago state the evidence of the predaceous habits of *Panorpa*, the typically scorpion-fly, is not so clear as one might desire...."

If man seizes or touches the larva it rolls round and feigns death. Though a certain amount of moisture in the soil is necessary for the healthy growth of the larva it seems to avoid too much moisture and comes out to the surface. The older the larva the less active it becomes and in later stages it is tinged with a rosy colour. In 10 to 15 days after hatching it attains the last stage; for example, the larva which came out of the eggs on June 7th and Sept. 25th attained to the final stage on June 17th and Oct. 10th respectively. The last stage lasts for a certain number of days,

and the larva then begins to burrow deeper into the ground or seeks dry places, probably to avoid moisture, and in the case of the second brood which has to pass through the winter, also cold. Having found a suitable spot it makes a small lump of earth (Pl. XIV, fig. 5) in the centre of which it excavates a cell and lies rolled up in it until it pupates. In the second brood this state last for the whole winter. My observations on the point under consideration are as follows :—

#### First brood

Sex.	Date of hatching.	Date of attaining last stage.	Date of pupation.	Duration of the last stage.
♂, ♀	June 7/'11	June 17/'11	July 31/'11	45 days.
♂	„	„	August 3/'11	48 days.
♂	June 26/'11	July 6/'11	August 11/'11	37 days.

#### Second brood

♂	Sept. 25/'11	Oct. 10/'11	May 5/'12?	211 days?
?	„	„	April 28/'12*	182 days.
?	„	„	April 29/'12*	181 days.

### VI. The Pupa.

The pupa (Pl. XIV, fig. 2) belongs to the type *Pupa libera*. At first it is ochreous white, but later it darkens and closely resembles the adult in colour. The entire body is curved first ventrally and then dorsally so that it represents the form 2. The compound eyes are large and dark purplish. On the vertex the anlagen of three ocelli are indicated by three purplish spots. The antennae are very long and filiform and consist each of 42 joints (in one male specimen I could actually count 50 joints, owing to the subdivision of some of the basal joints). The mouth parts are similar to those of the larva but slightly more elongated, though not produced into a beak like that of the adult. The thoracic segments are distinct and each bears a few setae. Legs are very long and the joints distinct. Tarsus five-jointed. Fore and hind wings spatulate, with well developed veins, and stretching backward as far as the fourth abdominal segment on either side of the body

\*Died in the larval stage.

between the second and third legs, covering a portion of the latter. At first they are colourless but later become darkened at the apex and the pterostigmatal regions, giving indications of the future wing-markings. The abdomen is conical as a whole, but each segment is cylindrical. The first to eighth abdominal segments are of almost equal length and are not so heterogeneous as in the adult; and each bears a pair of distinct spiracles. Near the spiracles as well as on the dorsal side there are a few setae. In the male (Pl. XIV, figs. 2, 3) the ninth or cheliferous segment is very conspicuous, the chelae being very long and stout, with the lateral portions uniting along the median line. Appendages very distinct. In the female the posterior segments gradually become more slender, and curved upward just as in the male (Pl. XIV, fig. 4). The terminal (10th) segment bears two diverging appendices, each consisting of two joints. Length 10 mm.

**a. Emergence of the adult:**—Though the pupa is motionless like most other pupae, it makes a jerky motion on being touched, and if it is brought out of its burrow, this motion continues until the pupa is restored to a natural situation. The pupal state lasts for six or seven days. My observations on this point are as follows:—

Sex.	Date of pupation.	Date of emergence.
♂	July 31	Aug. 7
♂	Aug. 3	Aug. 9
♂	May 5	May 17

As far as my observation goes the pupa comes out before the emergence of the adult insect from its burrow to or near the surface of the earth, where it casts out the pupal skin. The newly emerged insect, with all the characteristics of the imaginal form (with exception of its lighter colouration and soft body) remains motionless for a while on the ground but soon begins to move about.

## VII. Generation.

*Panorpa klugi* has two generations in a year. The perfect insect, emerged from the pupa that passed the winter, appears in May. As already stated, the first eggs are laid in May or June, and hatching out immediately



the larvae pupate at the end of July or the beginning of August, and the adult insects of the first generation appear in six or seven days. The entire period lasted in one case 69 days and in another case 71 days.

They were—

Sex	Date of egg laying	Date of hatching	Date of last larval moult	Date of pupation	Date of emergence	Total
♂....	May 31/'11	June 7	June 17	July 31	Aug. 7	69 days
♂....	"	"	"	Aug. 3	Aug. 9	71 days

The newly emerged insect lays eggs at the end of August or in September, the larva attains maturity at the middle of October and passes through the winter in the larval form in its burrow. At the beginning of May of the next year it pupates and the adult of the second generation appears at the middle of May.

Sex	Date of egg laying	Date of hatching	Date of last larval moult	Date of pupation	Date of emergence	Total
♂.	Sept. 18/'11	Sept. 25/'11	Oct. 10/'11	May 5/'12?	May 17/'12	251 days.

From the above we see that *Panorpa klugi* has two broods in a year. And as the adult insects of other species likewise come out about the same time, I believe most of our species of *Panorpa* have likewise two generations. This fact is mentioned neither by BRAUER nor FELT. Though it is somewhat hazardous to assume that the observations made on Japanese species apply to foreign species, still considering the duration of larval life in the European species, it is highly probable that the latter are similar to our own in this respect. This supposition agrees well with the statement in BREHM'S "Tierleben" (Bd. 9, p. 498, 1877),—"Weil durchschnittlich neun Wochen zum vollständigen Verwandlungen genügen, so werden vom Erscheinen der ersten Skorpionfliegen anfangs Mai zwei Bruten sehr gut möglich—." The same applies in my opinion also to the American species (*P. rufescens*), as not only the date of appearance of the larva does not greatly differ from our species but the further metamorphosis is supposed by FELT to proceed "in nearly the same manner" as actually observed by BRAUER in European species.



### VIII. A Few Remarks on Generic and Specific Characters.

As can be seen from the above, the morphology of the larva and pupa of our scorpion-fly is essentially quite like that of the European and American species, and such differences as are found between the larvae of *Panorpa* and those of other genera, such as *Bittacus* and *Boreus*,\* cannot be observed between the Japanese and the European species. So that the formation of a new genus, *Andops*, for the Japanese species, which ENDERLEIN proposes on the basis of the difference of neuration must be said to be unjustified, since the neuration itself is, according to my own observations,\*\* subject to variation, ENDERLEIN'S *Andops* has therefore at most a subgeneric value.

The breeding experiments on *Panorpa klugi* brought out the fact that the character regarded by M'LACHLAN as of specific value is a peculiarity of the first brood. I may therefore supplement the discussion of specific characters by describing some varietal forms. In the vicinity of Tokyo, in my breeding experiments, the first brood showed the type form of *klugi*. But in many other localities, as for example at Hakone, I have found only the form which must be referred to the second brood in the later season when the first generation should be found. I cannot therefore be certain whether the type form of *klugi* is of seasonal or local character. At any rate the other form should be recognized as a new subspecies, which is very variable in itself as *Panorpa nipponensis* NAVAS and *P. brachypennis* Miyake now seem to be only a varietal form of it.

#### *Panorpa Klugi* M'LACHLAN.

Trans. Ent. Soc. Lond., 1875, p. 185.

Subspecies **nigra** nov. subspec.

*Panorpa nipponensis* NAVAS, Mem. R. Acad. Ci. Bar. vol. vi., no. 25, p. 20 (1908).

*Panorpa brachypennis* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii, p. 9, pl. 1, fig. 6 (1908).

\*BRAUER described the larvae of *Bittacus* and *Boreus* in the paper quoted before.

\*\*The facts will be published in my further paper.

Body totally black (rarely piceous black on the 6th to 8th abdominal segments); legs testaceous. The general form of body as in the type form of *klugi*. Appendages of male rather shorter and more divalicate than in *klugi*. Wings very broad, moderate or narrow, apex rounded, with yellowish or more commonly testaceous yellow. Markings extremely variable: in some cases marked as in the type form of *klugi*, that is "a narrow black fascia beyond the middle, and a broad black apical space, both with sharply defined edges, one (sometimes two) small spot before the fascia, and frequently with a small spot on the inner margin between the fascia and the apical portion"; more commonly this latter small spot is obscure and the outer or inner or both margins become very irregular; sometimes the outer margin of fascia is furcate in its middle, forming a short branch, which often ends posteriorly on the hind margin (the form *nipponensis* and *brachypennis*); sometimes the fascia is very broad as in *japonica*. The apical dark portion is usually very broad and the inner margin is mostly sinuate.

Expanse 27 mm.—35 mm. Type: a series of specimens in the Agricultural College.

Possibly of general distribution in Japan. I have captured many specimens at Inokashira near Tokyo in May and June; on Takao-yama near Hachioji in May; at Hakone in July, August and September; at Nikko in July and August—in different years. Besides I have obtained many examples from various places, especially a good series from Echigo collected by Mr. HATAKEYAMA on Mt. Gozu, June '10 and from Kii collected by ISSHIKI on Mt. Iwawaki, Aug. '10.

Some of the specimens are very closely similar to those of *japonica*, but may above all be distinguished by the testaceous tinge of the wing and small size.

May 1912.

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## EXPLANATION OF PLATES.

## PLATE XIII.

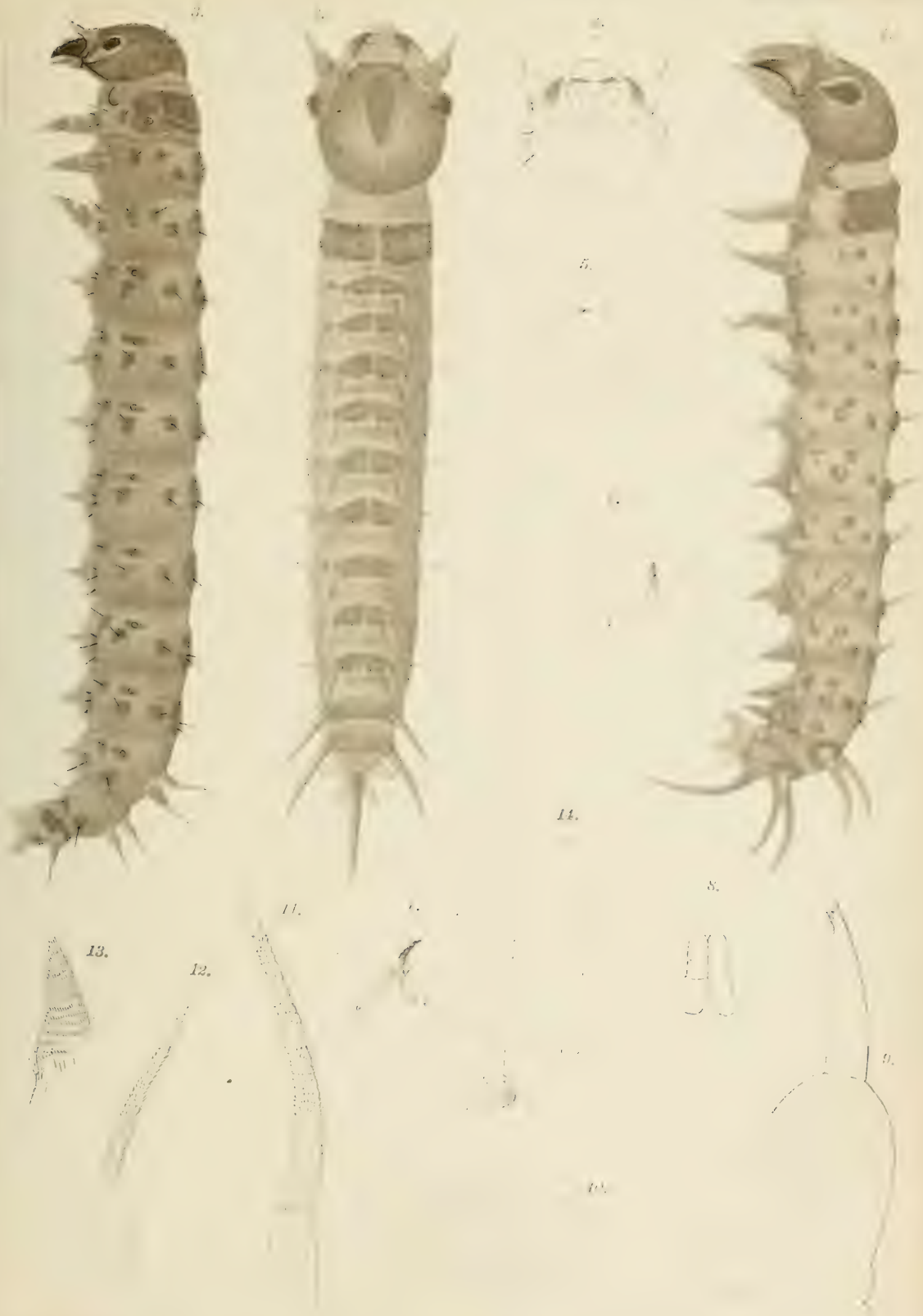
- Fig. 1. First stage larva, lateral view. ( $\times 46$ ).  
 Fig. 2. Do., dorsal view. ( $\times 46$ ).  
 Fig. 3. Last stage larva, lateral view. ( $\times 7$ ).  
 Fig. 4. Head of first stage larva, ventral view. ( $\times 86$ ).  
 Fig. 5. Hypopharynx of do., vent. view. ( $\times 130$ ).  
 Fig. 6. Right maxilla of do., vent. view. ( $\times 130$ ).  
 Fig. 7. Right mandible of do., vent. view. ( $\times 80$ ).  
 Fig. 8. Labial palpi of do., vent. view. ( $\times 130$ ).  
 Fig. 9. Right antenna of do. ( $\times 300$ ).  
 Fig. 10. Right eye of do. ( $\times 320$ ).  
 Fig. 11. Annulated seta of last abdominal segment of do. ( $\times 200$ ).  
 Fig. 12. Do. of last stage larva. ( $\times 80$ ).  
 Fig. 13. Aborted annulated seta of first abdominal segment of third stage larva. ( $\times 320$ ).  
 Fig. 14. Two kinds of setae found on first stage larva. ( $\times 500$ ).

## PLATE XIV.

- Fig. 1. Four-lobed anal fork of first stage larva, ventral view. ( $\times 65$ ).  
 Fig. 2. Male pupa, lateral view. ( $\times 7$ ).  
 Fig. 3. Cheliferous segment of do., vent. view. ( $\times$  about 8).  
 Fig. 4. Terminal segments of female pupa, lat. view. ( $\times$  about 7).  
 Fig. 5. Lump of earth made by larva. It is partly broken off in order to show the central burrow, within which the larva has to pupate. ( $\times 3$ ).  
 Fig. 6. Egg. ( $\times 42$ ).  
 Fig. 7. Aspect of egg just before hatching. ( $\times 23$ ).  
 Fig. 8. A flower of *Silene Armeria*, a petal of which is partly injured by adult *Panorpa*. + indicates the injured part. (Magnified).  
 Fig. 9. Thoracic spiracle of first stage larva. ( $\times 700$ ).  
 Fig. 10. Abdominal spiracle of do. ( $\times 700$ ).  
 Fig. 11. Thoracic spiracle of third stage larva. ( $\times 700$ ).  
 Fig. 12. Abdominal spiracle of do. ( $\times 700$ ).  
 Fig. 13. Thoracic spiracle of last stage larva. ( $\times 320$ ).  
 Fig. 14. Internal opening of spiracle into trachea, of last stage larva. ( $\times 300$ ).















# On the Life-History and Cytology of a new *Olpidium* with special Reference to the Copulation of motile Isogametes.<sup>1</sup>

BY

**S. Kusano.**

With Plates XV-XVII and one Figure in the Text.

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1. A short account of this work was read before the Tokyo Botanical Society, at the meeting held in December, 1911, and was published (in Japanese) in the December number of the Botanical Magazine, 1911.

## I. Introduction.

In the vicinity of our College a parasitic fungus furiously attacking *Vicia unijuga* Al. Br. ("Nantenhagi" in Japanese) has for some years been attracting my attention. Its annual occurrence at the same place, vegetating throughout the months from April to July, enabled me to study its life-history to the best advantage. I now propose to include it in the genus *Olpidium* of the Chytridiales, but as a species not yet described.

The chief object of the present article is to give an account of the zoospore copulation and the development of the resulting zygote of this fungus.

In the fungi, the copulation of motile isogametes has hitherto received no special attention, and notwithstanding that a few instances have already been given, our knowledge of this phenomenon is still in an unsatisfactory state. The first observer of this phenomenon was SOROKIN ('74) who described, in his new genus *Tetrachytrium* of the Chytridiales, the mycelial vegetative body as derived from the zygosporangium resulting from the zoospores. Ten years later, FISCH ('84), establishing a new genus *Recessia* among the same class of fungi, observed the formation of the zygote by copulation of the zoospores and its development, after infecting the host, into the resting sporangium. He reported the same fact also in *Chytridium Mesocarpi* Fisch (cf. FISCHER, '92, p. 126). Unfortunately the results of these older investigations made more than twenty years ago, very interesting as they may be, have not received a wide acceptance, on account, as FISCHER ('92) insists, of an apparent lack of continuous observations and of cytological evidences, or from the consideration that no one has since then succeeded to confirm them, or to find these fungi for reinvestigations.

At our present state of knowledge it appears possible to forecast the existence of this kind of the sexual act in the primitive fungi, supported by the fact that it is of wide-spread occurrence in the algae of similar rank, to which the former are considered to bear a close affinity, and by the fact that similar primitive sexuality is universally known in the Protozoa. Such a view seems to have been born in mind by the authors on the

Chytridiales; thus WORONIN ('78) in *Olpidium Brassicae*, CHATTON and BRODSKY ('09) in *Sphaerita*, and PERCIVAL ('10) in *Synchytrium endobioticum*, all, however, missing the direct observation of the copulation. This view was recently brought to light by GRIGGS' ('10) cytological study on his new genus *Monochytrium*, revealing the fact that the binucleate resting spore is formed by the fusion, according to his interpretation, of two amoebulae invading the host-cell.

The planogamete copulation in the lower fungi would afford a subject of the deepest interest. For in establishing this fact, the parallelism of the evolution of sexuality in the fungi and algae, which has hitherto been apparent in so far as the somewhat advanced process of sexuality is concerned, can be justified farther down to the level of the most primitive and simplest sexual process, and it will thus give a basis to the study of the phylogenetic relationship among the lower fungi themselves, or between them and the algae.

In treating the subject under consideration an attempt has been made to record fully the life-history of the organism, with which I am concerned, in order on the one hand to make the results I reached free from such serious objections as have been made against previous investigations on the same subject, and on the other to supply sufficient data to competent observers for judging whether my identification of this fungus is correct or not. I have studied, therefore, the living material repeatedly for a succession of two years in differing seasons. The inoculation of the host grown in pots enabled me to carry on daily observations in the laboratory room. As material for observing the germination the resting sporangia were collected in autumn and left throughout the winter months outdoors, submitting them as much as possible to the natural conditions of environment. The investigation on the living material was completed with the cytological study on the fixed material obtained from both the field and the inoculated pot plant.

I am now compelled to give first a somewhat tedious description of this singular organism, not only for the reason that it would be of some value in itself, but also from the point of view that it may fill a certain gap of our knowledge relating to *Olpidium*, of which a complete account, comprising both the life-history and the cytology, has not, so far as I know, been given hitherto.

The material for cytological study was collected from time to time during 1905—1911 and was fixed in FLEMMING's solution and acetic sublimate, and stained with HEIDENHAIN's iron alum haematoxylin and FLEMMING's triple stain. The presence of a heavily stainable oily matter in the resting sporangium has often prevented a clear differentiation of the nucleus. To make a satisfactory slide with it I put the section previous to staining in a mixture of one part of carbon bisulphide, one part of ether, and two parts of absolute alcohol. This treatment was somewhat effective in leaving out the stainable matter from the cytoplasm, as previous authors already found in staining sections of zygotes.

## II. Zoospores.

Shortly after a piece of the diseased part of the host is brought into water a large number of zoospores are easily liberated from a mature sporangium found therein. The zoospore is a colourless body containing a few shining granules in the central portion. During active movement it takes on an oval form with the narrower end directed forward, measuring  $6\text{--}7\ \mu$  in length and  $5\ \mu$  in breadth; but, becoming sluggish, it assumes a spherical form (Pl. XV, Fig. 1). Each zoospore is provided with a long posterior cilium, nearly 5 times the length of its body. The swimming in smooth long curves or in swift-gliding motion without a remarkable rotation of the body is due to the very rapid fish tail-like motion of the cilium. With the zoospore assuming a spherical form, after being fatigued from swimming, the movement of the cilium becomes slow, and its lateral bending causes a jumping movement to the body.

On several occasions abnormal forms of the zoospores came under my observation (Pl. XV, Figs. 2, 3). There are often larger zoospores than the average size. They are mostly multiciliate, the number of cilia increasing with the size of the body. The multiciliate form is usually spherical and exhibits a rotating movement. It is a compound spore developed by omission of the final division in fashioning the typical zoospore, and perhaps containing as many nuclei as cilia.

The swarming period of the zoospores varies considerably. In most cases



the newly hatched spores under a cover glass, at different days and hours, come in greater part to rest within 10 minutes (often 20—30 minutes). Only those zoospores which remain within the sporangium can swim about for a longer time (3 hours or more), as BUTLER ('07) observed in *Pleolpidium* (p. 122); some of them which during this time happen to escape come soon to rest and round off. The cause by which the spores within the sporangium can maintain their active movement for a longer time is not clear, but we think it very probable that a duration of activity would give them a better chance to escape.

The swarming period depends largely upon the temperature of the medium. When it is raised to 27°C., all the zoospores come soon to rest, while those kept in a cool place below 15°C. are almost all as active after 5 hours, in both diffused light and darkness, as at the beginning of liberation. According to ROSEN ('87), the zoospore of a certain Chytridiales swims for 44 hours. In our species it was observed under favourable conditions to continue the swimming movement for 21 hours.

Most of the zoospores observed under a cover glass begin to disorganize as soon as they come to rest. The rounded body at rest swells up, giving to its periphery a hyaline appearance, and then it ruptures, setting free the central granular contents. Sometimes it assumes an irregular form before complete disorganization. The first indication of the disorganization is the deformation of the cilium (Pl. XV, Fig. 4). At first its free end contracts into a small nodule. With the shortening and thickening of the cilium the nodule is drawn back to the body, while increasing its size, and finally attaches directly to the swollen body. In the zoospore of *Chytridium Zygnematis* (*Rhizidium Zygnematis* according to FISCHER, '92), ROSEN ('87) reported that the cilium forms a hoop which becomes so delicate and hardly visible as to make it impossible to determine its further fate. The nodule resembles in appearance the hoop mentioned by him, but from what I could observe I do not doubt in believing it to have been derived from a contraction of the cilium. The cilium contracted in this way is resorbed into the body, as was observed in the Flagellata by SELIGO ('86, p. 175).

The surviving active zoospores, after continuous swimming movement for shorter or longer periods, stop suddenly upon the substratum; then they

undergo an amoeboid deformation, sometimes creeping over the substratum, or they adhere to it with a pseudopodium-like process protruded from the head; and shortly after, attempting to detach from the substratum by a shaking movement, they dart away rapidly as soon as they are freed. Before coming to final rest they repeat this process several times.

A similar behaviour is already known of the zoospores of several other members of the Chytridiales. In some species the retraction of the cilium was observed during the amoeboid movement (BUTLER, '07, p. 120), but this is not the case in our fungus.

The zoospore which has come to final rest soon begins to encyst itself (Pl. XV, Fig. 5). The encystation takes place in most of the spores resting upon the surface of the host, and, under favourable conditions, even in those which have attached to the cover glass or slide. The body now becomes quite spherical, while the cilium still continues its swinging movement. Gradual contraction of the body takes place, changing its appearance from a granular to a refringent and homogeneous state (Pl. XV, Fig. 6). In the meantime the movement of the cilium, though becoming gradually slower, is yet clearly seen under the microscope. The cilium, during a very slow bending movement, often appearing to twist round the body, escapes suddenly from our sight. Even with careful repeated observations, I was not able to follow exactly the fate of the cilium at this instant. The sudden disappearance shows most probably that it is thrown off from the body, without any previous deformation. At any rate it can be stated that the fate of the cilium is here different from that confirmed during the disorganization of the zoospore.

At the time the cilium is lost, the body appears more compact than before (Pl. XV, Fig. 7). A distinct membrane is then precipitated round the body, with which the encystation process is closed. The encysted spore assumes a glistening globule.

### III. Copulation of the Zoospores.

During my daily observations on zoospores liberated on the slide it was quite usual to find them in the act of copulation. As it is a phenomenon in

the fungus group worthy of special attention and as it also seems highly desirable to get a comparatively accurate knowledge of it, I made a closer observation with the material from more than a hundred different sources. As showing a general behaviour of the zoospore during the course of this process, I shall give first in the following notes one of the cases recorded in my laboratory notes.

On May 3, 1911, a piece of diseased leaf carrying mature sporangia, after having been washed repeatedly with water, was introduced into the distilled water under a cover glass. Within a few minutes the zoospores began to escape abundantly from the sporangia, and after 10 minutes from the beginning copulation took place among them. Many spores were seen to come to rest on the cover glass, attaching with a pseudopodium-like process to the glass and deforming their body (Pl. XV, Fig. 9). They then swam away and again stopped to creep over the substratum in an amoeboid form. During the creeping movement two spores often met each other and kept closely together for a few minutes, both deforming their body. There was observed that one of them began to move the cilium rapidly and darted away, then the other did the same. I could observe also that three or more spores came closely together, separating after a short interval of time. In the meantime several pairs of the zoospores were found under the microscope to undergo an actual fusion (Pl. XV, Fig. 10). They were kept in contact for 5—10 minutes with a wide surface of the deforming body till the fusion began. On the surface of the body I could ascertain no such definite fusing point as may be seen in planogametes of the algae. The plasmic membrane was broken at any point of contact (Pl. XV, Fig. 11), and then the fused surface was so widened that a single plasmic mass resulted from the two bodies. This process lasted mostly from 1 to 2 minutes. The fused mass exhibited a prominent amoeboid deformation and movement, sometimes becoming a round mass with an irregular outline, sometimes stretching in one direction and then contracting and bending (Pl. XV, Fig. 12). At this stage the cilia were distinctly visible, but remaining functionless. After 5—10 minutes it assumed a round form, attaching with its pointed apex to the substratum (Pl. XV, Fig. 13), began to move the cilia rapidly and darted away in free movement.



The motile zygote thus formed is spherical or elliptical, resembling the zoospore in motion (Pl. XV, Fig. 14). The presence of two cilia in the zygote, often in different or opposite directions, induces a rotation to the body and a swimming movement in an irregular path.

The behaviour of the zygote is essentially similar to that of the zoospore; swimming for a few minutes it comes to rest (Pl. XV, Fig. 15) and begins again an amoeboid movement for a few minutes (Pl. XV, Fig. 16), and then the swimming movement is repeated (Pl. XV, Fig. 17). So that, in case the zoospore and the zygote are found mingled together in the medium, as is quite usual, a distinction between them should be scarcely possible, if we take the size, the number of cilia, and the mode of movement—characters all so little distinct indeed as to be overlooked—out of consideration.

After about one hour from the first swimming movement, the zygote comes to final rest (Pl. XV, Fig. 18), and the encystation ensues in quite the same manner as in the zoospore (Pl. XV, Fig. 19). The encysted zygote is smaller than the swimming one (Pl. XV, Fig. 20).

The above account of the copulation process and the behaviour of the zygote was based on the observation with those zoospores which had been previously at an active movement for some time and came to rest on the cover glass or slide. However, with the zoospores crowded together after swimming for a moment on the surface of the host near the sporangia from which they escaped, the copulating and encysting process is much more simplified. The gathering of the zoospores at a short distance from the sporangia is probably due to less activity, on account of which they are incapable of traversing a wide space, rather than to a certain attracting action exercised by the host. As they mostly lie in close contact with each other, the copulation is effected easily among them, without the swimming movement, in order, so to speak, to find their mates. The zygote thus formed may undergo, as in the former case, more or less deformation, but the swimming movement is omitted and the encystation follows immediately as if to hasten the infection.

MECHANISM OF THE COPULATION. No external difference can be recognised between the copulating zoospores. But from the fact that any two spores



coming into contact are not always induced to fusion, but, after attempting it for a few minutes, may detach again from each other, it appears highly probable that a certain internal differentiation is called forth in becoming the gamete. Such differentiation, if it does exist, may take place not only between the zoospores from different sporangia, but also, as has been observed, between those derived from the same sporangium, as ascertained in the lower algae, for instance *Chlorochytrium Lemnae*. Although the first act leading to the copulation is to bring the gametes closely together, there is no attracting action between them. Based on my accumulated observations it can be stated that the meeting of the gametes is quite occasional, taking place during their swimming or creeping movement. So that there may occur a meeting of zoospores, between which no sexual affinity exists.

The assumption of the existence of a certain period or age in the zoospore, at which copulation is possible, can be drawn from several facts relating to the conduct of the zoospore. Two actively swimming spores may frequently happen to meet each other, but they do not show any indication of copulation or of such tendency, and seem to hasten on in their passage. When an actively swimming spore meets another spore resting on the substratum or during the creeping movement, it continues its onward movement in some cases, appearing quite indifferent to copulation. It is observed that to ensure the copulation both gametes must be at a state in which they are capable of a creeping amoeboid movement. The young, or newly hatched zoospores are in a continuously and actively swimming state, and are incapable of coming to rest at any desired time, but the older ones are disposed to come easily to the creeping state. It is the latter zoospores that can stop from swimming when dashed against a creeping one and can fall soon in a similar condition as its mate and enter into copulation. However, it is not necessary in all cases, that such a preparation should be commenced first after coming into contact. Several times I could observe that two creeping spores lay closely together but apparently did not touch, and came by a mere chance into contact with a narrow surface during their random movement. Reacting perhaps to the contact stimulus, they were drawn more closely and widened their contact surface.

The responsibility to the contact stimulus, leading to the fusing process, may be a character possessed by all the gametes, or perhaps even by the zoospores, when they arrive at a certain stage of their swarming period. We may now assume that this character can bring the gametes sometimes to an improper and sometimes to a proper pairing for fusion. By the improper pairing no breaking of the plasmic membrane of the gametes can take place, inspite of their endeavouring, so to speak, to find a breaking point on their surface, which I conceive from their gliding movement for a few minutes along the contact surface. I have to attribute this unsuccessful fusion to the absence of sexual affinity between them.

When more than two spores come into company, their behaviour in this sexual action is more interesting. It is a frequent occurrence that a pair of spores, while vainly attempting a fusion, receive unexpectedly another spore which soon comes to concern itself with the same matter. The three spores keep together in close contact for some time, exhibiting a gliding movement among them (Pl. XV, Fig. 10). We then see the fusion taking place between one of the previous two and the third spore (Pl. XV, Fig. 11). While the fusion is proceeding, the other member of the original pair, which has been endeavouring to fuse, begins to separate from the other two, and regaining its original form, swims rapidly away. In other cases three spores in contact are unsuccessful in their attempt to fusion between any two and finally depart in an amoeboid or an immediate swimming movement.

From what has been stated above it will be seen that the sexual action in the present case is at an exceedingly primitive state, and in reality a sexual distinction between the gametes is still obscure. What we can conceive here of sexual affinity existing between the zoospores, or properly gametes, seems certainly to be nothing else than a definite condition of tension of the plasmic mass. ATKINSON ('09 a, p. 332) observed in *Lagenidium rabenhorstii* Zopf an occasional conjugation of zoospores as being due to the variations of tension. He considers that the want of fresh water in the medium comes into play in this case. The matter is more complicated in my case and no evidence can be found for assuming that the water in the medium has any concern with this process.

THE CONDITION OF COPULATION. In the first part of the series of observa-

tions I could not confirm the copulation, but when I had succeeded in seeing it, I saw it at nearly all of the observations carried on for more than two weeks from the beginning of May, 1911. From what follows it seemed clear that in some cases the copulation took place easily, while in others it was difficult to be observed. This remarkable fact leads us to the inquiry as to this variance of the behaviour of the zoospores taken from different sources. It does not appear that the gametangium and the zoosporangium are morphologically differentiated and further the gamete, following the general rule, is incapable of developing into a parasitic individual without copulation. In fact, the sexuality is here too primitive to manifest such a differentiation. Hence what we wish to deal with is the point whether the copulation is influenced by external conditions. The experiments carried out with this view are as yet unsatisfactory and the results are consequently incomplete, but I venture to record them in that state, as affording a suggestion for further investigation.

Among the lower algae, in which motile isogametes are known to occur, it has already been proved by experiments that the zoospore may function as an asexual form or a gamete, according to external conditions (temperature, nutrition, light, etc.) (cf. LOTSY, '07; OELTMANN, '05).

In *Protosiphon*, for instance, the zoospores are induced to copulate when exposed to 1–24° C., while not in 25–27° C. In my experiments carried out on differing days, the temperature on some days was 15° C. and rose till 22° C. on other days. Within this range of temperature the zoospores liberated in the distilled water, which contained a small piece of the host tissue and to which new water was added several times during the continuance of the experiment, did not show such difference in their behaviour as could be attributed to the change of temperature. On the other hand, at the same hour of the day, and consequently under the same temperature, the zoospores from certain sources copulated easily and in great abundance, while those from other sources were tardy to copulate or appeared quite indifferent to this process. The copulation took place as well below 15° C. as in 22° C. So far with these insufficient observations the relation between temperature and the copulation could not be conclusively determined.

The occurrence or non-occurrence of the copulation was quite unaffected



whatever the medium was, distilled water, tap water, or water containing substances diffused out of the host tissue introduced into it.

I then proceeded to compare in this respect the zoospores from those sporangia which had just attained maturity with those mature ones which had been inhibited for a certain time to dehiscence. The former zoospores could be obtained from the diseased spot, on which water was poured the preceding day to make all the mature sporangia liberate the zoospores and thus to leave on the spot only immature sporangia, whose whole surface soon dried and kept so till the next day. The zoospores to be liberated from the same spot a day after this treatment should be those developed in a sporangium that had just come to maturity. To prepare the latter zoospores the host plant was brought into the room and its diseased spot containing apparently mature sporangia ready to rupture, whenever water is supplied, was kept dry for 1—3 days until it was used for the experiments. The host-cells of these sporangia during these intervals became brownish throughout the wall as well as the protoplast, showing inactivity or death, notwithstanding the sporangia might remain alive waiting for water. Having treated the zoospores from both sources under the same external conditions, we could observe a somewhat distinct difference in their action of copulation. Those from the older sporangia appeared more active and, repeating the creeping movement more frequently, showed as if to be very busy in their business. The larger percentage of them went into the formation of the zygote. On the other hand, those derived from the younger but just matured sporangia were somewhat dull in movement, the creeping movement was far less frequent, and the resting condition followed soon. In the majority of cases the copulation was exceedingly rare or not observed.

The inhibition of the discharge of the sporangium, leading it to survive in an inactive host-cell, would seem to affect the nutrition of the zoospore origins unfavourably, so that the zoospores formed under such condition may be considered to be in a hungry state. Therefore, I now come to advance provisionally the view that the copulation is induced by insufficient nutrition or hunger, to which the zoospore origin is brought. This view is in agreement with facts already ascertained in the motile isogametes of some algae.



How far this view can be held true in the normal course of the fungus development in the field will be considered under the heading "The resting sporangium" to be given later in the present paper.

#### IV. Infection.

After encystation the zoospore and the zygote present quite a similar phase of further development up to a certain stage. They go soon to infect the host-cell. The mode of their infection accords mainly with that presented by other members of the Chytridiales (BUTLER, '07; ZOPF, '84). It begins with the germination. On the surface of a cover glass or slide, upon which they have encysted, they produce 2—3 hours after encystation a short process, with which they adhere to the substratum. Their content is then contracted in an irregular mass, leaving between it and the wall a clear space (Pl. XV, Figs. 8, 21). Without further developmental change the contracted content becomes disorganized later and finally breaks down, the wall, however, remaining intact and distinct. On the other hand, when they occur on the epidermis of the host plant, the process on their surface functions here as the infection tube and its apex proceeds to perforate the epidermal cell. The plasmodium of the spores migrates through this tube into the host-cell (Pl. XV, Fig. 22). The naked spherical plasmodic mass thus passed out of the wall remains for 10—20 minutes attached to the apex of the infection tube (Pl. XV, Fig. 22*c*), then, being freed, it moves away into the plasmodic membrane of the host (Pl. XV, Figs. 22*d*, 24). On the emptied wall of the spore the infection tube can be seen as a shining process. The wall and the tube can remain intact for a long time.

We observe in the encysted zoospore, and perhaps also in the encysted zygote, an abnormal mode of germination, in case, it seems, the condition is unfavourable for infection. On applying to the trichome of the host or to the bottom of the medium, it sends out a longer or shorter germinating tube as a hyphal filament (Pl. XV, Fig. 23). I did not ascertain whether the filament effected the infection or not. I could find only a few filaments whose apices pushed against the wall of the host, which might show the possibility of perforating it.

In other cases there was found a thicker and shorter tube than the above mentioned filament, which perforated the wall of the host and in which the plasm of the spore was accumulated as an elongated mass.

### V. Endophytic Development.

All the individuals of the fungus, soon after infection, are as a rule brought closely to the surface of the host nucleus, where they commence their growth as spherical bodies (Pl. XV, Figs. 24, 25). No amoeboid or any other deformation is ever observed at all. As to the approach of the fungus bodies to the host nucleus, it may perhaps be approvable to assign it to the active movement of the fungus reacting to the chemotactic stimulus exerted by the nucleus. However, my continuous observation points otherwise. Watching an infecting spore I found that, as soon as the migrated plasmic mass detached itself from the infection tube, it moved rapidly along a plasmic string towards the lateral side of the host-cell across a certain distance, and applied to the wall at the opposite side to the nucleus (Pl. XV, Fig. 24*x*). So rapid a movement is due, in my opinion, to the gliding action through the string. It then moved slowly along the lateral wall towards the nucleus, but advancing half the way it retreated some distance and stood there for a time stationary. This is evidently a floating movement carried on by the plasm of the host, in which it lies embedded. During the retreating movement of the fungus I actually saw the reversal of the plasmic stream. Thus, being transferred by the plasm, it can finally be brought into contact with the nucleus. After attaching to the nucleus it becomes free from the conveying action of the stream. It seems very probable that in bringing the nucleus and the fungus bodies together adhesion plays an important rôle.

The growth of the fungus body is very rapid. Under favourable condition of the host-cell it was observed to attain nearly twice the diameter of the zoospore when examined 18 hours after infection (Pl. XV, Fig. 25). In the subsequent development its diameter is on average doubled each day, for the succeeding 3—4 days (compare Figs. 25-28). Hereafter the growth is not uniform in all individuals, being influenced by the spatial relation (the

size of the host-cell and the number of individuals occurring in one host-cell). When one or two individuals occur in a large host-cell, the space is yet sufficient to allow an unrestricted further growth, while it becomes soon occupied by the fungus, when numerous individuals occur in company. This spatial difference gives rise directly or indirectly to the difference of the maturity period, sooner with individuals in company (Pl. XV, Fig. 31).

Until 3—4 days after infection the fungus body, whether originated from the zoospore or the zygote, grows all at the same rate and in the same appearance, being globular and coarsely granular. It is at the subsequent stage that we can recognize its further fate to develop either into a zoosporangium or a resting sporangium.

#### A. ZOOSPORANGIUM.

The fungus body developing into the zoosporangium grows in a spherical form as far as the space in the host-cell admits. When it enlarges so much as to strike against an obstacle, i.e., the wall of the host or sister individuals, it deforms accordingly (Pl. XV, Fig. 29). When it occurs singly, the growth goes on unrestricted till it occupies almost wholly the cavity of the host-cell, and consequently assumes the same form as the latter (Pl. XV, Figs. 31-34), while the aggregated sporangia acquire generally a polygonal shape from compression. On account of this circumstance the size of the mature sporangia varies in an exceedingly wide range, the maximal size attaining to as large as the host-cell ( $120\mu$ ), while the smallest one is  $20\mu$  in diameter.

When the fungus body is approaching its maximal growth, a membrane appears on its surface which, becoming gradually distinct, differentiates into a hyaline sporangium wall.

At an early period of growth we recognize in the body a less dense central portion showing a vacuole, but in surface view of the living specimen it is difficult to decide whether the vacuole is sharply delimited from the surrounding cytoplasm. This stage is followed by the disappearance of the vacuole, whereas the cytoplasm is distributed uniformly but in a loose reticulum. Approaching maturity there appears a distinct regular network of fine granules (Pl. XV, Figs. 30, 32*a*, 33), and shortly before the liberation of



the zoospores this structure is replaced by a homogeneous mass of finely granular consistence (Fig. 32*b*). This stage is immediately followed by the final fashioning of the zoospores (Fig. 32*c*).

At the time the sporangium is about to assume the network of granules, it begins to develop on its wall the beak or exit tube, whose apex, penetrating the host wall, comes outside as a papilla. It is so orientated as to occur invariably on the side facing the free surface of the host-cell. On surface view (Pl. XV, Figs. 33, 38, 40) the beak presents two concentric rings. The space between them is somewhat refractive. The refracting portion assumes in side view (Figs. 37, 39) a convex lens. It arises, as FISCHER ('82, p. 327) observed in *Rozella*, from the swelling or gelatinization of the sporangium wall, the outer ring showing its boundary and the inner one the basal outline of the protruded papilla from the centre of the swollen portion. Later the swollen portion is dissolved just under the beak and leaves a hole, when the beak ruptures, as an exit for the zoospores.

With chlorzinc-iodine the sporangium wall takes on a faint blue or violet colour showing the cellulose reaction, but we recognize a more or less yellowish tint. The cellulose reaction is more apparent on the swollen portion.

The beak is exceedingly short. Its apex becomes swollen (Pl. XV, Figs. 39, 40), when the zoospores are ready to escape, and its sudden rupture causes a large mass of the zoospores to migrate out of the sporangium at once.

Among aggregated sporangia in a single host-cell there may occur those which cannot come into contact with the outer wall of the host and consequently are not able to develop the beak in the normal way. These sporangia elongate more or less till their tapering end strikes against the host wall and develops into a beak (Pl. XV, Fig. 31).

The number of the beaks to be formed on a sporangium is not constant. In smaller sporangia, either found aggregated in a larger host-cell (Fig. 35) or singly in a smaller one, only a single beak is developed as a rule, but in larger sporangia we find many beaks, commonly 4—5, and occasionally 6—7 in each (Pl. XV, Figs. 33, 34). In either case the escape of



the zoospore takes place through one beak. This is due, in my opinion, to the possession of the different resistant power of the gelatinized beaks to the increasing osmotic pressure exerted by the sporangium coming to dehiscence. Although all the beaks may be functional, it will be rather rare that they all possess quite an equal resistant power and consequently are broken simultaneously. I could observe only once that the zoospores escaped at the same time through the three beaks which had been broken simultaneously. In most cases the rupture of one beak makes the other beaks remain intact and functionless.

The manner with which the zoospores are expelled is somewhat variable. As a rule, the sudden rupture of a beak causes a large mass of zoospores to come out at once, which can dart away instantaneously in different directions, while the remaining ones pass out through the beak one by one continuously, appearing as if they are carried outside the sporangium by a streaming action. Under a favourable condition the sporangium becomes quite empty in 2—3 minutes. There often remain a few spores till a few hours later, incapable of finding the exit and finally becoming motionless. Sometimes the discharged zoospores are found bound together into a mass at the front of the beak, which has a rotating movement and from which each spore is freed one by one until all are dispersed in the medium. Often it is observed that a similar mass of zoospores remains for a while motionless, then it begins rotating and breaks up into separate active zoospores. In this case it appears to show that the spores are bound together by a certain substance like mucus as assumed in some Chytridiales. But it is not a fact; I take it as due to the entanglement of still immovable cilia. It is highly probable that at the time of discharge the zoospores may be in active or inactive condition, according to whether the osmotic pressure in the sporangium causes later or earlier rupture of the beak in respect to the fashioning of the zoospores; the formation of a ball of immovable spores is due to the earlier eruption of the sporangium.

Believing that the beak ruptures due to the osmotic pressure exercised by the sporangium, it can scarcely be doubted that the escape of a larger part of the zoospores at the first instant is due to the physical process. A jostling motion begins immediately in the remaining ones which causes

them to pass through the narrow opening of the beak one by one. Watching carefully the manner of passage, we find that the zoospores approaching under or near the opening appear to be carried outside passively by a streaming action. At later times, when the number of those remaining in the sporangium is much lessened, they manifest a different manner of escape. With a few spores remaining till 2—3 hours later, I noticed that they swam actively about or were beating the sporangium wall, attempting, as it were, to escape like a caged animal, and occasionally orientating their direction of movement towards the opening, they succeeded easily to escape. If the opening is narrower than the breadth of the spores, as is often the case, they cannot pass through freely, and a considerable time is required to get out by constricting the body, the more time this takes the more they are fatigued in swimming. This action manifests a sort of "ingenuity" (ATKINSON, '94) in the attempt to escape. Therefore, it may be stated that the escape of the zoospores is passive at the first instant and active at later periods. However, we cannot yet arrive at the conclusion that the latter method is connected with the osmotactic, thigmotactic, chemotactic, or adelphotactic stimulus.

In the mature sporangium the final fashioning of zoospores begins after water is supplied on the surface of the host-cell where the beak projects out, so that a certain time is invariably required for the liberation of zoospores. It is at this interval of time that the division of the cytoplasm into separate spores, the increase of turgidity of the sporangium, and the gelatinization of the beak take place. The readiness of the mature sporangium for receiving water is indicated by a finely granular homogeneous appearance of the contents. Without supply of water the sporangium retains this condition until the host-cell becomes inactive and the fashioning of the zoospores becomes entirely impossible.

#### B. THE RESTING SPORANGIUM.

The resting sporangium is spherical with a smooth yellow brittle exospore and thicker hyaline endospore (Pl. XV, Fig. 45). Treating previously with chloralhydrate, the pressure under the cover glass makes the

sporangium slip out of its outer wall and expose the endospore. Both walls do not give the cellulose reaction. The sporangium lies singly or, more generally, grouped in each host-cell, sometimes in company with the zoosporangium. In contrast with the zoosporangium the resting sporangium has approximately uniform size, except in an extreme case where it occurred too much aggregated. The spatial relation is not so much accounted for as in the zoosporangium, so that we find usually a wide space in the host-cell round the adult resting sporangium.

As we have already stated, at an early stage of development there is no difference in the rate of growth between both kinds of sporangia (see Pl. XVI, Fig. 9), but subsequently the resting sporangium finishes its enlargement earlier and hastens to develop the membrane round its body and to become more granular and denser in consistence. It can be distinguished from the similar-sized zoosporangium by a more intense brilliant orange colouration of its content with chlorzine-iodine.

The resting sporangium is found in the same diseased spot as the zoosporangium (Pl. XV, Fig. 32) and indeed, as stated above, in the same host-cell as the latter (Fig. 30). This condition claims a certain relationship between both sporangia concerning the period of their maturity. When the numerous host-cells happen to contain zoosporangium dehiscing all at once, they must be thrown simultaneously into inactivity by the wound made by the beak, whereby the neighbouring host-cells of the resting sporangia interfere with their nutrition or activity, as we may conceive by their becoming brownish. As a necessary consequence, the growth of the resting sporangia must be finished prior to the appearance of this symptom in their host-cells. We come therefore to the view that for the maturity of the resting sporangium the condition of the entire host plant or its organ gives no direct influence; it is the condition of the diseased spot that regulates the maturation. It may be ascribed in part to this reason that the resting sporangia are found quite matured on the still young leaves or stems as early as the first generation of the zoosporangium on the same diseased spot is over (early part of the vegetative season) (Pl. XV, Fig. 32).

I could find at the beginning of April some diseased spots containing almost exclusively resting sporangia, some containing the zoosporangia as



much as the resting sporangia, while some contain only the zoosporangia. The same is true of spots that appeared subsequently. Therefore, it may be concluded that the resting sporangium is formed at successive generation throughout the fungus development, in conformity with the general rule of the resting sporangium formation of the Chytridiales as summarized by FISCHER ('92).

Referring to the proper function of the resting sporangium, it may be of interest to inquire about the biological significance of so early a formation and also about its condition. As to the former point I cannot find any appropriate explanation on the necessity of the preparation of such a hibernating sporangium already at the beginning of the vegetative season. It would seem probable that it is merely brought forth influenced by inner or outer conditions but without any special biological significance. The activity of the entire host plant which may be variable of course at different periods of the vegetative season will have no concern with it, since the infection experiment with the host or its portion at different stages of development, and under favourable and unfavourable conditions for its growth, gives no evidence for it. Also it does not seem to bear a direct relationship with the seasonal change of climatic conditions.

Although the resting sporangium may be formed at any period, still the results of field observations for several years favour the assumption that the relative number of the resting sporangia with the zoosporangia changes with a certain regularity at varying periods; at an early period the zoosporangia predominate over resting sporangia, while the reciprocal relation is prevailing towards the later period. Approaching to the end of the vegetative season of the fungus (July), the zoosporangia become exceedingly rare, the new infection resulting chiefly in the development of the resting sporangium, no matter if the host plant or host-cells may be as vigorous as in early spring or not.<sup>1</sup> It is certain that such a tendency of development is favourable to the fungus for existence. As to whether it is brought forth

1. In June I found very vigorous young shoots regenerated from the cutdown mother-stock of the host. The nutritive condition of the diseased spots on these shoots appeared to be favourable just as on the young shoots in the early spring, in contrast with those on shoots which had already become older. Notwithstanding, most of the fungus bodies were developing at this season into the resting sporangia.



in connection with the climatic condition or with an internal condition, such as the repetition of generations or the periodicity of the developmental cycle, we have no evidence to prove or disprove. Yet about the direct cause of the untimely formation of the resting sporangium I may be allowed to make a few remarks.

Bringing here the evidence obtained from the cytological study which will be given in a subsequent section, it is quite evident that the resting sporangium originates from the zygote, while the uncopulated zoospore gives rise to the zoosporangium. Hence the problem attached to the formation of the resting sporangium must now be turned upon the formation of the zygote. We have already remarked that the copulation takes place predominantly in the zoospores retarded in liberation. As the dehiscence of the zoosporangium is connected with the absence or presence of water over the host-cell, the zoospores may be subjected to this condition at any time during the vegetative season. In the field the water supply is rain or the dew drop. On a rainy day and after a clear night, therefore, the zoosporangium can discharge the zoospores at the proper time; otherwise the discharge is postponed until the condition becomes favourable. In April the weather in Tokyo, or more generally in Japan, is rather rainy, and the zoosporangium is mostly dehiscing at any time of day and night whenever it ripens. Approaching to June it becomes more dry, being accelerated by the rise of temperature, and, the medium in which the zoospores are liberated being dew drops, the zoosporangium attained to maturity at noon must postpone its discharge till the next dew fall, hence the predominant occurrence of the resting sporangium at this period. Thus I can arrive at the conclusion that the view induced from the experiments on the cause of the zoospore copulation and the fact obtained from the field observation on the occurrence of the resting sporangium are in such accordance as sufficient enough to assign the formation of the resting sporangium to the internal condition of the zoosporangium, the zoospores from which give rise to the former.

One point worthy of note in this connection is that the retardation of dehiscence of the zoosporangium due to absence of water may bring the fungus to the hungry state. If the most intimate cause of the zoospore

copulation is its hungry state, we must take into account here the nutritive condition of the host-cell as well as the water supply. I think this notion is correct, as it is in harmony with the facts obtained from field observations. At a later vegetative season the host-cell containing zoosporangia ready to dehiscence becomes mostly brownish showing disorganization. The zoospores derived from the sporangia in such host-cells should be in the hungry state. On the other hand, at an earlier period the host-cell does not attain to such condition when the zoosporangium is about to ripen, except the case where too many sporangia (Pl. XV, Fig. 31) are found in one host-cell which then becomes brownish and incapable of nourishing the parasite sufficient enough to grow up as much as the space admits. As to why the host-cells come at the later period to the disorganized state earlier with respect to the period of discharge of the zoosporangium infected, I am of opinion that the dry air comes into play chiefly. The host-cells, whenever thin-walled, are disposed at this period to fall into an excess of transpiration which hastens their death.

From the considerations above given we can formulate the view that the formation of the resting sporangium depends upon the nutritive condition of the zoosporangium which liberates the zoospores becoming the origin of the former. Such conditions may arrive at any period of the whole vegetative season, by daily fluctuation of the environment or by the internal condition of the host-cells in relation to the parasite. The general seasonal change of environment, however, is such that tends the parasite to produce more numerous resting sporangia when approaching the later season.

It may be added that in the diseased spot, which I understand appeared first in the spring and produced undoubtedly by the zoospores derived from the wintering sporangium, I could ascertain the presence of the fungus bodies that can develop into the resting sporangia. This is a confirmation of the fact that the zoospores derived from the resting sporangium can by copulating into the zygote give rise to the generation of the resting sporangium without interruption by the zoosporangium generation. In this case, whether the resting sporangium formation is assigned to the same cause as we have proposed above or not, we require further observations. Still, at our present state, it appears possible that the wintering

sporangium may come under the similar condition as the zoosporangium. When it comes about to fashion the zoospore, which takes place in this case in the soil, there may occur a deficiency of water and a retardation of the zoospore liberation. The water in the soil where the zoospores must be liberated can scarcely originate from the dew drops, at least not in early spring time. Rain water is the sole medium in which zoospores are liberated and through which they attain to their host. It may be considered, therefore, that the germinating resting sporangium, if it must wait for the rain water for a longer time, liberates the zoospores liable to copulate. Fortunately the subjection of the wintering sporangia to this condition is rather seldom, for the rainfall during this season is frequent enough to ensure that most sporangia liberate the zoospores that infect immediately the host without copulation and to make them develop into the zoosporangia apt for a rapid propagation of individuals.

GERMINATION. During the resting period the sporangium contains larger and smaller globules like oil drops (Pl. XV, Fig. 45). When it begins to germinate in spring, the globules diminish in size and eventually disappear, and the content of the sporangium becomes homogeneously granular. As the germination process advances, the endospore shows a differentiation into outer and inner layers. The outer layer swells up and goes to dissolve by gelatinizing, while the inner one remains distinct till the last (Pl. XV, Fig. 47). The swelling of the sporangium contents may bring this remaining layer of the endospore into close contact with the exospore as before (Pl. XV, Fig. 48). While the protoplast proceeds to fashion the zoospores, the endospore produces a beak on its surface, which, penetrating the overlying exospore and, if present, the dead wall of the host-cell, come outside in the water into which the sporangium is immersed (Pl. XV, Fig. 47 *a*). The zoospores can escape through the beak, as observed in the zoosporangium. They are quite similar in all respects to those derived from the zoosporangium (Pl. XV, Fig. 48). The host-cell containing the emptied resting sporangium resembles that of the emptied zoosporangium in possessing a perforation made by the beak (Pl. XV, Fig. 49).



## VI. Cytology.

### A. ZOOSPORANGIUM.

The fungus body derived from the encysted zoospore is first found in the cytoplasm of the host as a dense naked plasmic mass. Under high magnification the nucleus appears as a somewhat faint vacuole, in which a chromatin mass representing without doubt a nucleolus is contained (Pl. XVI, Figs. 1, 2).

With the growth of the body a corresponding multiplication of the nucleus takes place (Pl. XVI, Figs. 3-6). Up to the few-nucleate stage the cytoplasm is compact; hereafter a vacuole begins to appear in the centre and the nuclei are arranged in the periphery (Pl. XVI, Figs. 7, 8). In further growth the vacuole becomes larger and larger, as already observed in fresh material (Pl. XVI, Figs. 10, 12, 13). This stage is soon followed by the disappearance of the vacuole, and the cytoplasm is arranged in irregular loose heapings round each nucleus, thus forming a network structure and leaving between them irregular spaces (Pl. XVI, Figs. 11, 17). At this stage the nuclei become larger and present a distinct structure, and we can recognize the nucleolus, chromatin, and a few linen threads within a well-defined wall (Pl. XVI, Fig. 16).

In other members of the Chytridiales (BUTLER, '07) and in the Saprolegniaceae (DAVIS, '03), this feature of the sporangia is considered as the stage just before the zoospore formation. So the heapings separate from each other and go to fashion themselves as the zoospores. LOEWENTHAL ('05) has shown in *Olpidium Dicksonii* a similar feature of the zoospore formation and figured the peripheral arrangement of zoospores along the sporangium wall (see his Fig. 17), showing the direct cutting of the plasmic wall surrounding the vacuole into the spores. In my case this is rather exceptional, being only met with in the aggregated sporangia that come to maturity without such further growth as to fill up completely the host-cell, perhaps from insufficient nutrition. In this case the central vacuole is especially large and the protoplast is considerably stretched out round it (Pl. XVI, Fig. 10), as LOEWENTHAL observed. From such sporangia we get



loosely packed zoospores. In the other but usual case, the transition from the single-vacuolate to the network stage does not mark the approach of maturity. Further growth takes place, increasing the amount of the cytoplasm and the number of nuclei, whereby the reticulum becomes finer and finer, diminishing the clear space of the meshes (Pl. XVI, Fig. 18). At the close of the maximal growth, when the last nuclear division is over, by which the nuclei of the zoospores are constructed, the cytoplasm becomes of a quite homogeneously denser state throughout, leaving no apparent vacuoles (Pl. XVI, Figs. 19, 20).

The above feature, exhibited after the disappearance of the central vacuole, is in strict accordance with that presented during the development of the sporangium in *Synchytrium Puerariae* (KUSANO, '09). In its primordial form, just produced by the segmentation of the whole fungus body, it contains a few nuclei scattered in a loose cytoplasm reticulum. The further growth induces the increase of the cytoplasm and diminution of the vacuoles with corresponding multiplication of nuclei. Attaining to maturity the sporangium becomes filled up with the dense cytoplasm and innumerable small nuclei of the zoospores. It will be seen, therefore, that in both fungi the vacuolate stage of the sporangium pertains only to its early stage of development, the mature stage being represented by a dense consistence of the protoplast.

During the growing period, or the vegetative phase of the fungus, we observe an increase of the nuclei in size. Entering the period of the zoospore formation, or the reproductive phase, they are reduced in size in successive divisions. At the former period the manner of the nuclear division is somewhat obscure; in abundant material, which I was able to examine, almost all nuclei have an appearance of the resting stage, revealing in no case the occurrence of the typical mitotic division. However, combining the several nuclear figures reproduced in Pl. XVI, Figs. 14 and 15, it is not difficult to draw the probable line of division. There are found such nuclei which contain only a prominent nucleolus—the chromatin nucleolus—as a visible element within a faint membrane. In the same fungus body two equal or unequal nucleoli are found in contact to, or detached from each other in a clear space surrounded by a faint membrane. They are certainly

produced by the bipartition of a single nucleolus. Often it is impossible to recognize the presence of the membrane in such a nucleus. As showing perhaps the next stage, the two nucleoli are separated a short distance, each having a wide clear space round it. Certainly this stage is followed by the precipitation of the membrane surrounding the clear space. The occurrence of two nuclei in pairs, facing the side where the nucleolus lies attached to the membrane, is rather usual in my slides (Pl. XVI, Fig. 15), and I take such a figure as showing the pair of the daughter nuclei just constructed. At this stage the chromatin and linin are far less in amount. The most complex structure of the nucleus with a vacuolate nucleolus of a disc-shape and prominent chromatin granules lying on the linin threads or along the distinct nuclear membrane (Pl. XVI, Fig. 16) would show certainly the subsequent stage.

If I understand the nuclear figures given above aright, the division resembles amitosis. Differing from the usual amitosis, there is disappearance of the nuclear membrane and the chromatin as well as linin. It is very likely the "Promitose" proposed by NAEGLER ('09) in the nuclear division of *Amoeba*.

In the latter period the occurrence of the mitotic division is quite certain, though I cannot give here all dividing stages. The nucleolus disappears and a few similar-sized chromatin granules become distinct, while the nuclear membrane is at this time faint (Pl. XVI, Figs. 18, 22, 23). Such structure of the nucleus represents perhaps the prophase stage. In a full grown zoosporangium just about to develop the beak (Pl. XVI, Fig. 19), I found the nuclei all at the spindle stage (Pl. XVI, Fig. 24). However, the arrangement and the number of chromosomes were not presented clearly. Unfortunately no other stages could be studied, but I believe the above figures are sufficient to warrant the conclusion that the karyokinesis here is of a different type from that usually found in the vegetative phase of the Plasmodiophoraceae, but rather in accordance with what I described in the secondary nuclei of *Synchytrium Puerariae*.

From the above, we can distinguish two different modes of the nuclear multiplication, one in the vegetative phase and the other in the reproductive phase, as already known in other Chytridiales and the Plasmodiophoraceae.

NEMEC ('11) has ascertained in *Sorolpidium* that in young parasites the nucleolus persists during the division, and after dividing into two halves, each enters the daughter nucleus in a similar way as found in the vegetative phase of *Plasmodiophora*, *Sorosphaera* (BLOMFELD and SCHWARTZ, MAIRE et TISON), and *Spongospora* (OSBORN). In the older parasites the nucleolus disappears, according to him, previous to division, and the usual karyokinetic spindle appears. While my fungus agrees in respect to the presence of two modes of the nuclear division with all these organisms, I may remark that the division in its vegetative phase is somewhat different. During the division only the nucleolus is present, while in the Plasmodiophoraceae and *Sorolpidium* the nucleolus and chromatin persist distinctly and undergo the division in themselves.

As to the mode of the fashioning of the zoospores, that is, of the separation of the cytoplasm into spores, I am not able to give a satisfactory explanation, as the minuteness precludes an exact observation. As already stated, in the mature sporangium where the final nuclear division is closed (Pl. XVI, Fig. 20), and which is ready for the cytoplasmic division, the contents appear as a compact homogeneous mass. No progressive division was observed in the fixed material, such as to produce sausage-like parts as in *Hydrodictyon*, but a clear space appears in the cytoplasm all at once between each two nuclei, cutting off the cytoplasm in as many polygonal parts as the nuclei. Each part, however, does not seem to have been immediately separated freely, since the fixation of the material at this stage results in throwing all these parts into a compact mass shrunk from the sporangium wall (Pl. XVI, Fig. 21). This is perhaps the final stage that the sporangium can attain to without receiving water from outside, the stage at which the sporangium contents assume, when observed alive, a reticulum of fine granules. The granules are in my opinion an oily matter, now extruded from the cytoplasm going to divide into spores, and arranged marking the boundary of each division. A clear space visible between the polygonal parts of the cytoplasm (Pl. XVI, Fig. 21) is in all probability produced by the occupation of this extruded matter. With the disappearance of the reticulum of granules in the mature sporangium, occurring normally first soon after being immersed into water, the polygonal parts may be actually



separated from each other as the zoospores. Probably the granules are dissolved into an osmotic substance which can absorb water into the sporangium from the outside and increase its turgidity. With these processes the zoospores are suspended in the fluid inside the sporangium. In the whole aspect the mode of fashioning the zoospores above explained is in accordance with what I observed in the zoosporangium of *Synchytrium Puerariae*.

In the nucleus of the zoospore we can recognize small chromatin granules along the nuclear membrane, but no prominent nucleolus (Pl. XVI, Figs. 25, 26). A large chromatin nucleolus found in the youngest fungus in the host-cell is evidently formed by the condensation of these granules into a mass (Pl. XVI, Figs. 1-6).

#### B. THE RESTING SPORANGIUM.

Among the spherical and naked fungus bodies in the host-cell we find already at the earliest stage of development somewhat larger ones (Pl. XVII, Fig. 1). As they are binucleate, we understand that they originate from the encysted zygotes. It must, however, be remembered that a similar form is also assumed actually by the endophyte originated from a zoospore, if it has grown to the binucleate stage. The criterion as to from which, the zoospore or the zygote, the endophyte in such a form has been derived must be, therefore, laid upon the point how far its development has advanced after infection. It cannot be doubted the binucleate form among uninucleate ones, both having been infected at the same time, originates from the zygote. This form of the endophyte is destined to develop into the resting sporangium.

During the growing period the nuclei remain intact, while their size increases gradually. At the first stage they have the simplest structure, only a small nucleolus being prominent (Pl. XVII, Fig. 2). As they grow, the nuclear membrane becomes clearer and the enlarging nucleolus becomes vacuolate and flattened into a disc-shape. Attaining the maximal size, the linin threads and chromatin granules become conspicuous, assuming a reticulated structure (Pl. XVII, Figs. 3-6).

At the time the resting sporangium is approaching the maximal growth its centre becomes occupied by a vacuole, and the cytoplasm,



being denser towards the periphery, assumes rather a coarse network structure. The two nuclei occupy the peripheral position, usually opposite each other (Pl. XVII, Fig. 5).

A membrane now begins to appear on the outer surface of the sporangium (Pl. XVII, Fig. 7). At this time the nuclei undergo the most remarkable change. The nucleolus which has been attached to the inner side of the nuclear membrane appears now as displaced outside it (Pl. XVII, Fig. 7). It gives the impression that the dislocation is an artificial effect, occasioned while sectioning or mounting on the slide. However, it being a universal phenomenon in the nuclei at a similar stage and being supported by the phenomenon succeeding it, we must take it as a normal process partaken by the nucleus of the resting sporangium. A marked change following immediately the dislocation of the nucleolus is the nuclear budding taking place at the tip of the nucleolus (Pl. XVII, Figs. 8, 9, 10). This bud gradually increases in size and can attain nearly the form and size as the mother-body, resulting in the formation of a dumb-bell-shaped nucleus with the nucleolus in the median portion (Pl. XVII, Fig. 9). This process goes on *pari passu* on both nuclei in the same sporangium.

The above mentioned change of the nucleus I was able to observe in a number of the resting sporangia taken from the same diseased spot or the same host-cell, where most of them may be naturally at similar stages of development because of their equal age.

At the next stage we see the disintegration of the budded portion (Pl. XVII, Figs. 11-12). Its wall is broken and the contents are thrown into the central vacuole. This process may take place either while it is still attaching to the mother-body or soon after.

The quantity of the chromatin-like bodies thus appearing in the vacuole may correspond at first to that of the contents of both budded portions (Pl. XVII, Fig. 13), but later they appear to be increased considerably in number, and they come to be arranged in a reticulate structure as seen in a nucleus at the resting stage (Pl. XVII, Figs. 14, 15). We recall here the phenomenon of hyperchromatophily.

This peculiar phase in the nucleus may be considered as expressing an unusual type of amitotic division. In separating into two nuclei the

prominent nucleolus lying between the separating portions is also divided and each half enters the daughter nucleus. But too early a disintegration of one of the daughter nuclei appears to show the extrusion process rather than amitosis. With this process the two nuclei diminish apparently the chromatin and achromatin granules. The chromatin granules are now found mostly attaching to the inner side of the nuclear membrane, whereby the latter becomes more conspicuous than before. Also the nucleolus becomes smaller and often faintly stainable.

When the sporangium is going to precipitate the inner wall, the dissolution products of the nuclei begin to be distributed from the vacuole in the surrounding cytoplasm, while the vacuole in turn comes to be replaced by the cytoplasm until it disappears finally (Pl. XVII, Figs. 16, 17). In consequence the cytoplasm becomes deeply stainable (Pl. XVII, Fig. 18). At first there exists a clear distinction between the cytoplasm and the stainable substance distributed uniformly in it as small globules, but at advanced stages of the resting sporangium the stainable character of its contents is increased very much, so much so that it is scarcely possible to recognize the cytoplasm but the heavily stained globules arranged densely. Since the staining reaction of these globules is quite similar to that of chromatin, the visibility of the nuclei is at this stage greatly hindered. The difficulty in observing the nuclei is further increased by their diminutive size and contents, only a small nucleolus and a few chromatins being visible (Pl. XVII, Fig. 18). On the basis of the series of changes through which the sporangium has attained such a structure, I come to the conclusion that the stainable substance is presented most probably by the rearrangement of the nuclear substances found accumulated previously in the central vacuole. On this ground we have to compare this stage of the sporangium with the "akaryote stage" recently reported in several members of the Plasmodiophoraceae (MAIRE et TISON, '09, '11; BLOMFIELD and SCHWARTZ, '10; OSBORN, '11) or the chromidial stage known for certain Protozoa, or *Synchytrium* studied by PERCIVAL ('10), though it may not be quite homologous.

On attaining the last-mentioned stage, the development of the resting sporangium is said to be closed. It passes then into the resting condition.

The reaching of this condition is seen at widely differing periods of the vegetative season, according to whether the formation of the sporangium begins earlier or later.

Certain analogous features of nuclei are presented in the cyst of *Amoeba muris* Grassi (WENYON, '07) in which autogamy is known. The nucleus of the encysted amoeba divides into two soon after encystation. "The stage with two nuclei is one of long duration and in this stage the nuclei are reduced in size by a throwing out of chromatin. The chromatin passes out of the nuclei into the protoplasm causing the latter to stain very deeply, especially around the two nuclei, which themselves stain only faintly. The chromatin is then either dissolved in the protoplasm or is thrown out of the cyst" (WENYON, p. 178). His figure (Pl. X, Fig. 14) corresponds exactly to my Fig. 18 (Pl. XVII). He adds that the loss of chromatin reduces the nuclei to a much smaller size, which is also true in my case. He further mentions a stage corresponding to the akaryote stage known in the Plasmodiophoraceae, and notes that the nuclei after the loss of chromatin give off two reduction bodies which are ultimately dissolved in the protoplasm or remain as darkly staining granules, and that the division of the nuclei results in the formation of four nuclei which are reduced again into two by conjugation. As far as I could observe in my fungus, the essential difference in the above features lies on the omission of the typical akaryote stage and the reduction bodies. There might be considerable difficulty in my case in getting the serial stages indicative of these nuclear features; yet I am not conscious of having missed them all.

In the material fixed in early winter the content of the sporangium is found as small globules, taking heavily the chromatin stains and obscuring the presence of the nuclei. With approaching spring there appears a differentiation between the cytoplasm and the stainable substance. The latter occupies the central portion as large globules which look like oil drops. The globules are variable in size and number, often fusing together. In January and February I was able to see two distinct resting nuclei situated peripherally as before (Pl. XVII, Fig. 19). With FLEMING's triple stain we can usually distinguish there a reddish spherical nucleolus and somewhat violet chromatin granules besides less stained linin threads. At the beginn-



ing of April, a few days before the appearance of the disease on the host in the field, the sporangium has undergone the dissolution of the stainable matter and the cytoplasm appears homogeneously granular, being hardly stainable. Among such sporangia we can find several stages of the nuclear feature indicative of karyogamy and the multiplication of the conjugated nucleus (syncaryon). In some of them the two nuclei are found as yet widely separated as before, without any essential change in their structure (Pl. VXII, Fig. 20). I found also a few sporangia in which only a single larger nucleus occurred centrally situated (Pl. XVII, Figs. 22-24). In all which I could find, their membrane was distinct and the contents somewhat poor, lacking the nucleolus, but having, though only very few, chromatin granules. Its central position and larger size lead us to consider it to be a conjugated nucleus. The stages previous to this are difficult to be observed. But the general structure of two nuclei found in contact, the one overlapping the other (Pl. XVII, Fig. 21), would in high probability indicate their coming in contact preparatory to conjugation.

The material at my hand is still insufficient to demonstrate the successive changes occurring in this single nucleus. Notwithstanding, it is not impossible to draw the conclusion that it may divide by karyokinesis. In Pl. XVII, Fig. 24 the nuclear contents, chiefly the chromatin granules, are found gathering altogether in a peripheral portion of the cavity, leaving the other portions quite vacant. It seems to indicate the synapsis stage, though of course the finer structure is not comparable to the corresponding stage in higher plants. In Pl. XVII, Fig. 25, which I would like to mention as a stage immediately following it, few chromatins are found in a denser portion of the cytoplasm. An accurate counting of the chromatins is impossible; they may be four or five, or thereabout. Their approximately uniform size appears to show their being the chromosomes, showing the prophase stage. The spindle figure which follows it is not found, but Fig. 26 may be taken as showing the telophase stage. I can mention here two figures (Figs. 28, 29) in which the metaphase stage of the closely lying two nuclei is somewhat clearly shown. The spindle fibres are obscure, but these figures are sufficient to indicate that the two daughter nuclei from the conjugated nucleus have gone to perform the



mitotic division without departing from each other. The two nuclei lying closely together, each containing only a stellate nucleolus (Pl. XVII, Fig. 27), may be considered as the daughter nuclei just formed from the conjugated nucleus.

In the multinucleate sporangia it is highly difficult to get a clear idea of the dividing stages of the nuclei, as at these stages they exhibit only an obscure outline and give no definite figure. However, from the figures we have reproduced in Figs. 30-33, which show only those stages that can afford a somewhat clear view of the nuclei, we may draw an idea as to what change the nuclei do undergo during their multiplication. In the youngest nuclei the visible content is an irregular body (Pl. XVII, Fig. 31). It becomes more or less stellate, the condensation of chromatin granules takes place in its matrix (Fig. 32), and the granules are gradually extruded into the surrounding clear space, resulting in the resting nucleus with a sharp outline and usually with a reticulate structure (Fig. 33). In a sporangium with an increased number of nuclei, larger and smaller chromatin granules are found at certain nuclear stages, uniformly scattered throughout the denser cytoplasm in such a manner that we are scarcely able to point out a sharp demarkation of each nucleus (see Pl. XVII, Fig. 34). Similar stages came frequently under my observation. Fig. 35 shows the stage of fashioning the zoospore. The endospore has partly dissolved and become thinner. The resting nuclei with a clear outline, containing a few chromatin granules, are arranged closely in the cytoplasm becoming now denser. This stage of the resting sporangium corresponds to that of the zoosporangium having approached to the zoospore formation (compare Pl. XVI, Figs. 18, 20).

### C. DISCUSSION.

The cytology of the zygote in the lower fungi and algae is known very little; so far as it has been studied until now, the results are very divergent according to the different species, and there is no strict accordance in *Olpidium* on *Ficia* and any of the above quoted plants whose zygote is well investigated. In the Diatomaceae a case was reported where two copulated gametes become each binucleate. One of the two nuclei in each gamete degenerates soon and the karyogamy is established with the remaining one.

In other species of the same family the gamete nucleus multiplies into four by successive divisions into two and only two of them perform the karyogamy producing two zygotes, while the remaining nuclei degenerate without conjugation. The division of the gamete nucleus previous to conjugation is further reported in *Basidiobolus*. According to WOYCICKI ('04), the nuclei of both conjugated hyphal branches derive the beak nuclei and gamete nuclei, and the latter undergo the amitotic division. The karyogamy takes place between one of the daughter nuclei thus produced, while the sister nucleus in each gamete disintegrates. No more minute details of these two divisions previous to conjugation of the gamete nuclei are given in these instances, and the reduction of chromosomes is here uncertain, though the feature may find a certain accordance with that of most Protozoa where the "Reductions-kern" is of a wide occurrence in the gametes (PROWAZEK, '07; HARTMANN, '09; consult the numerous papers published in the "Archiv für Protistenkunde").

The study on the zygote of *Spirogyra* (KARSTEN, '09; TROENDLE, '11) and *Zygnema* (KURSSANOW, '11) has recently brought out the evidence for the fact that the reduction division takes place after conjugation of the gamete nuclei. Though the number of chromosomes is not observed, the first two divisions of the zygote nucleus in *Closterium* are considered by some writers as performing the reduction of chromosomes. In *Olpidium* on *Vicia* the exact number of chromosomes is unfortunately unknown, but the account of the zygote nucleus we have already given would favour the view that the reduction takes place after conjugation of the gamete nuclei, in harmony with the process in the zygote of the last-mentioned algae.

The two nuclei of the resting sporangium, which are in themselves the nuclei of the copulating zoospores, become by functioning as the gamete nuclei materially unequal to the zoospore nuclei, since they have thrown out a certain portion of their contents in the way already described. As this process, taking place previous to conjugation, may express the nuclear division, one might infer that it indicates the reduction phenomenon as commonly seen in the Protozoa, as zoologists adopt the small nuclei derived at the corresponding stage as the reduction nuclei or bodies. It is sure that the gamete nuclei in *Olpidium* are in this way remarkably reduced of

chromatin and achromatin, but to prove or disprove whether the nuclear feature in the sexuality of this primitive fungus is homologous to that in the equally primitive animals (Protozoa) needs further investigations. At present we are inclined to the view that the reduction of the content in the gamete nuclei has no concern with the true reduction of chromosomes. The extruded substance may be largely trophochromatin. Referring to the cytology of *Synchytrium* (KUSANO, '09) I am impressed by this view. The uninucleate stage of this fungus represents the growing or vegetative phase, during which the nucleus is concerned with the elaboration of food materials, calling forth the accumulation of a large amount of the chromatic substance in this connection. Entering the reproductive phase where the rapid multiplication of nuclei is a chief feature in the fungus body, the useless content is extruded as trophochromatin. The two nuclei in the resting sporangium of *Olpidium* on *Vicia* may be comparable in some extent to the primary nucleus of *Synchytrium*, and the extrusion of their content at the close of the vegetative and before the beginning of the reproductive phase can be assigned to the same cause as we have maintained in *Synchytrium*. In *Olpidium* the zygote must perform a rapid growth to develop into the sporangium. Compared with the development of the zoosporangium, with which the zygote enlarges at the same rate up to a certain stage, the indivisible two nuclei of the growing zygote must be in a more active condition than the numerous nuclei of the zoosporangium in respect to nutrition. Also in contrast with the zoosporangium, the resting sporangium must close its maximal growth earlier, that is, the vegetative phase, with the accumulation of sufficient reserve materials for further development, with which the activity of the nuclei comes into play. While precipitating the exospore, the nutrition of the resting sporangium becomes interrupted. It is just at this stage that the extrusion of the nuclear contents is observed. Although the extruded substances may probably contribute the formative material to the multiplying nuclei in the germinating period of the sporangium, their bodily connection with the newly derived nuclei, as ascertained in the Plasmodiophoraceae and in certain Protozoa, or in some Chytridiales (BALLY, '11), cannot be proved in the present case (ref. to the review of the chromidial bodies by DANGEARD, '10 and PROWAZEK, '10). It may be



speculated that, so far admitting the function of the nucleus relating to the nutrition, the gamete nuclei in the resting sporangium seem to possess both properties which we apply separately to the large nucleus and small nucleus found differentiated in certain Protozoa (PROWAZEK, '10). As *Olpidium* stands in its organization in the same rank as the Protozoa, such a conjecture is not quite impossible.

The view on the significance of the extrusion-bodies of the nucleus will be justified, if the similarly behaving zygote of the Endosphaeraceae be ascertained to manifest a similar cytological phase during its development.

From the above consideration it should be understood that the vegetative stage of *Olpidium* is the x-generation, while the 2x-generation is represented by the zygote nucleus which is soon followed with the occurrence of the reduction division by the x-generation. In this respect its life-cycle is comparable to that of the Conjugatae. OSBORN expresses the opinion that a quite similar phase takes place in *Spongospora*, with which he points out its resemblance as regards the nuclear constitution to most Myxomycetes. According to JAHN'S ('11) reinvestigation on the Myxogastres, the plasmodium has the diploid chromosomes, the reduction taking place before the spore formation. In the Myxomycetes there is a disagreement in the chromosome number at the plasmodium stage. It may be diploid in some and haploid in the other. The diploid form may be in harmony with the Protozoa, to which the Myxomycetes are closely allied. The haploid form in some Myxomycetes may show their similarity to other Protophyta. This fact suggests further researches into whether it is possible to distinguish, in the vegetative period of the Protista, the protophytic type (haploid form) and the protozoan type (diploid form) as regards the number of chromosomes.

In connection with the karyogamy in the resting sporangium we must direct our attention towards the mode of the nuclear division which has taken place during the vegetative phase of the zoosporangium and through which the gamete nucleus has been derived. I have previously regarded the division to be amitotic-like, corresponding more to promitosis. If it is truly a usual amitosis, the zoospore nuclei should be unequal in component. It then leads us to the inference that the reduction division in the zygote nucleus which has been derived from such heterogeneous nuclei of the zoospores (behaving



here as gametes) loses its true significance. To decide whether this is a mere assumption or a fact, we must prove by further investigations whether the arrangement of the various stages of the nucleus, as I already mentioned, from which to formulate its dividing manner, is in their proper sequence or not, or whether they are in themselves a complete series of the stages of the dividing nucleus or not. At present, believing this method of division as most probable, I would say that the caryosome represents here a single chromosome and its bipartition can distribute equally the hereditary substance in the daughter nuclei.

### VII. The Host and the Habit of the Fungus.

The epidermal cell of either leaves or stems is attacked by the fungus. The infected spot on the leaf remains light greenish, and the surface of the leaf is depressed at this spot towards the infected side (Text-fig. 1). The mesophyll of the diseased spot is hypertrophied with the enlargement and



Text-fig. 1. One healthy and two diseased shoots of *Vicia unijuga*.

the increasing number of cells (Pl. XV, Fig. 51). All epidermal cells on the spot, both infected and intact, are much enlarged and often swell up and

cause the rounded outer surface, making the spot more or less verrucose.

The formation of an abnormal tissue in the diseased spot may depend upon the period of infection with respect to the developmental stage of the leaf. Later infection induces but little deformation as well as enlargement of cells, whereas the fungus is found growing in cells of the normal form (Pl. XV, Fig. 33).

The diseased spot on the stem is characterised by a more vigorous formation of abnormal cells in heaps (Pl. XV, Fig. 50). When furiously attacked, the accelerated growth in length on the infected side causes on the stem an irregular curvature (Text-fig. 1) and perverts in great measure its normal growth in length. The shoot attacked at an early period of growth (April) is often greatly suppressed in development and remains in a dwarfed condition.

The influence of the fungus upon the protoplast of the host-cell is not remarkable. A slight enlargement of the nucleus and more or less increase of the cytoplasm may occur. The nucleus is deformed by compression when the fungus body or bodies grow to occupy a greater part of the cell cavity, but it can be active during the vegetative phase of the fungus. The cytoplasm encasing the zoosporangium is disorganized generally before the latter attains to maturity.

After the zoosporangium discharges the zoospores, the host-cell loses turgidity and often shrinks being compressed from the surrounding turgescerent cells. When the resting sporangium advances to precipitate the inner wall, the host-cell begins to die, the dead protoplast being left round the sporangium as brownish granules.

The diseased spot on the host becomes visible first at the end of March or at the beginning of April, when the young shoots of the host developed from the perennial root-stock grow a few centimeters long. For closer observation on the progress of the fungus development I transplanted, on April 4, 1911, the attacked stocks of the host in pots and brought them into the laboratory. From the size the fungus had attained, I guessed the infection to have taken place 2 or 3 days before. On April 9, the aggregated sporangia had already come to maturity, and introducing them into water the zoospores were easily liberated. On April 11, I put

pieces of the diseased portion of the host, containing mature sporangia, into water drops upon still inclosed or just opened leaflets. Three days later the diseased spots became visible as a slight depression of the surface and as being discoloured. On the 16th, the sporangia on these spots discharged the zoospores as soon as water was poured upon their surface. Inoculation with the zoospores from the zoosporangium in the first generation was again tried on April 12 and 16, and the second generation of the zoosporangium finished in nearly the same interval of time. Although it appears that a rapid or slow development of the fungus may depend upon the activity of the host, it may be generally stated that the symptom of the disease is visible in 3—4 days after infection and the zoosporangium comes to maturity in 5—10 days. Broadly speaking, a zoosporangium generation ends under favourable conditions in a week. As zoosporangia may be found in the field up to July, their generation should be repeated at least ten times during a vegetative season, so that the propagation of the disease must be considerably great. A successful infection will, however, take place *ceteris paribus* chiefly at the earlier half of the vegetative season, when the host is still young and its whole portion is easily subject to the attack of the fungus. For this reason, we generally find on the adult shoots more numerous diseased spots on the lower than on the upper portion. Certainly the rapid development of shoots at later periods renders their growing portion soon resistible to the attack of the zoospores.

It is a biologically interesting fact that all the epidermal cells of the diseased spot show a rejuvenescence and their outer wall remains thinner and softer. These cells, therefore, are easily subject to the attack of the fungus. On this account, the zoospores can infect the epidermis of the same diseased spot during 2 or 3 successive generations, until the increased number of the attacked cells brings the spot itself to death.

In favour of the development of the fungus there is a tendency that the diseased spot appearing on the upper portion of the shoot (to be produced at later periods of the season) is especially hypertrophied, producing a larger number of abnormal cells. They are produced from the cells surrounding an infected cell, by their radial multiplication and also by the parallel division to the surface of the epidermis (Pl. XV, Fig. 50). I am of opinion



that the presence of these abnormal cells is more necessary for the fungus at this vegetative period than at the earlier one, since at this stage the rapid development of the host renders the newly produced healthy epidermis sooner resistible than that coming at the earlier part of the season, and thus leaves only the diseased spot as ensuring the infection of the fungus, except younger portions at or near the growing point.

### VIII. Systematic.

The morphological characters and the developmental features of the fungus, I have so far described, agree fairly well with the generic character of *Olpidium*, a member of the Chytridiales (FISCHER, '92, p. 22.). However, they present a certain point of resemblance with other genera of the Olpidiaceae, in which *Olpidium* is included. In *Olpidium*, as far as we know at present, the exit tube in the zoosporangium is generally single (exceptionally two, according to FISCHER's description), but in the present species, many tubes are usually developed in larger sporangia, of which only one is practically functionary. In possessing many tubes the fungus may show an affinity to *Pleotrachelus*, but it cannot be identified on account of inconstancy of this character. The zoosporangium occupies nearly the entire cavity of the host-cell, bringing both walls of the sporangium and the host-cell in close contact, as observed in *Pleolpidium* (FISCHER, '92, p. 43); a closer examination, however, shows that the disorganized plasm of the host is often found interposed between both walls, and the wall of an emptied sporangium may easily shrink off from the host wall, proving that both walls are in fact not brought together so intimately as observed in *Pleolpidium*. We also see that the sporangium wall does not come in contact throughout its whole surface when the host-cell has an irregular or wavy outline.

On account of the zygote formation of the zoospores and its development into the resting sporangium, our fungus resembles *Reessia*, though differing from it by the absence of amoeboid movement of the vegetative body. The latter genus was synonymised by FISCHER ('92) to *Olpidium*, since, according to him, except the feature of the copulation, the morphology of the zoosporangium and the resting sporangium appears to agree exactly with that of a



certain *Olpidium*, namely *R. amoeboides* Fisch with *O. Lemnae* Fisch and *R. Cladophorae* Fisch probably with *O. endophyllum* A. Braum. If the formation of the zygote can be regarded as a diagnostic character, the genus *Reessia* may now be established, embracing, besides the species already described by Fisch, our present species. However, while most species of *Olpidium* receive but little attention on this point and require a fresh examination as regards the behaviour of zoospores and the cytology of resting sporangia, we are not yet justified in taking this character as distinctive of both genera. At present, attaching much weight to the amoeboid movement of the vegetative body as a chief point of distinction, if the genus *Reessia* be preserved, our fungus should be included most properly in *Olpidium*.

*Monochytrium* created by GRIGGS ('10) is characterised by the amoeboid movement of the vegetative body and by the resting sporangium resulting from the fusion of two young amoeboid bodies after infection. Except a slight difference in the period of copulation, this genus agrees well with *Reessia*, to which he has made no reference in his paper. When epitomising his paper in the Botanical Gazette, Vol. XLIX, 1910, ATKINSON has already expressed this view. GRIGGS studied this fungus in a fixed material only and a larger part of its life-history was left untouched, so that the affinity of our species to his cannot be made out satisfactorily. Yet, so far as the cytological features are concerned, I find such a striking similarity between them that I cannot pass it over without making reference to his paper in this place.

The resting spore he described coincides almost exactly with mine in size as well as the cytological features. He mentioned a central vacuole during its developmental stage, which I can confirm in my fungus. The deeply staining granules he found on the cytoplasm reticulum seem to correspond to those which appear in my fungus after the budding of the nuclei has taken place. He did not give the budding of the nuclei. Whether it is quite absent or he missed this stage is not clear. In an older spore only a single yellowish wall was mentioned. Can it be possibly a mature spore? Is there no formation of the inner wall as in my case when it advances further in development?

In both fungi the relation between the parasite and the protoplast of the host-cell reveals no difference.

As regards the different periods of the zoospore copulation in both fungi it may be said to deserve a distinctive character. In my slides, in the youngest stage of the parasite, uninucleate bodies (derived from the not copulated zoospores) are found lying in contact. We also find together with them binucleate young parasites, which are either the zygotes or the zoosporangia at a first growing stage. As to the break of the plasmic membrane for fusion between closely lying individuals which have a very faint outline, there prevails so great an obscurity in my case, that if I could not observe the actual copulation of the living zoospores, I would have attempted, as for the origin of the binucleate young body developing later into the resting sporangium, to concept incorrectly the fusion of the plasm between these youngest parasites. Of course such an obscurity may not happen in the case of *Monochytrium*, but without evidence on the living material an objection cannot be avoided against acceptance of this remarkable fact.

His description on the development of the zoosporangium accords essentially with mine, and from his illustrations I understand that the zoosporangium grows to fill up the host-cell as in my case. Unfortunately he was not able to study the mode of discharging the spores. It appears to develop an exit organ, instead of rupturing in itself. The perforation on the host-cell wall, which he regarded as being made by the parasite during infection, appears to be impropotionally large, judged by his drawing (his Fig. 13). It is noticeable that it appears like a perforation made by the beak of the zoosporangium of my fungus.

An abundant occurrence of the individual parasites in a very limited area of the host led him to the view that the zoospore may be amoeboid rather than ciliate. I may note that a similar distribution of individuals is observed in my case, even though ciliate zoospores are produced.

So far the several points of coincidence above referred to, regarding the cytology of GRIGGS' and my fungus, lead me to think that even the points of difference mentioned above would be probably such as may be brought into harmony by further investigations. However, so long as the most important characters, such as the form of the zoospore, the structure of the zoosporangium, etc., are not given more satisfactorily and the behaviour of

the amoebulae is not followed out exactly in a living state, and further referring to his description, it is not wise to synonymise my fungus with *Monochytrium*.

Most forms of *Olpidium* are aquatic, being parasitic generally upon microorganisms. The terrestrial forms of this fungus we know at present are *O. Brassicae* (Wor.) on *Brassica*, *O. Trifolii* Schröt. on *Trifolium*, and *O. simulans* DeBary et Wor. on *Taraxacum*. The life-history of these species are not yet studied very thoroughly. According to FISCHER ('92, p. 51), *O. Trifolii* is included in *Synchytrium* as *S. Trifolii* Pass. This and *O. Brassicae* show many points of difference from my species, but *O. simulans* shows the closest resemblance as far as it has been described by previous authors. SCHROETER ('92, p. 70) proposes to place it in *Pleolpidium* on account of the zoosporangium fusing with the wall of the host-cell. The sporangium wall of my fungus shows such a tendency, but it is, as already remarked, of inconstant character, manifested merely by a special relation of the size of both the host-cell and the sporangium. The description of *O. simulans* is still incomplete, and the structure of the wall of the resting sporangium is unknown. In *Pleolpidium* it is generally spinous, though, as BUTLER pointed out, it is not constant, even in the same species, while in *Olpidium* it is invariably not spinous. In this respect, my fungus coincides with the latter genus.

On the ground of the above statement I come now to describe the fungus on *Vicia* as a new species of *Olpidium* with the following diagnosis:

***Olpidium Viciae* n. sp.**

Zoosporangium in epidermal cells, solitary or in company (often more than 20) even with resting sporangia, the form and size variable, being like the host-cell when solitary or being small and polygonal from compression when aggregated, 20—120 $\mu$  in diameter. Exit tube very short, single in smaller sporangia, numerous (4—7) in larger ones, one of them being generally functioning. Zoospore colourless, elliptical or oval, 6—7  $\times$  5 $\mu$ , with a posterior cilium.

Resting sporangium solitary or aggregated (often more than 10) in epidermal cells, 17—47 $\mu$ , with smooth yellowish exospore and thick hyaline



endospore, originated from the motile zygote derived from the copulation of zoospores. Germination by producing zoospores.

On stem and leaf of *Vicia unijuga* Al. Br. Komaba in Tokyo. April to July.

### IX. General Remarks.

While our knowledge on the sexuality of unicellular organisms has recently made great progress, the Chytridiales do not as yet furnish many details in this respect. In some highly organized genera (*Polyphagus*, *Zygorhizidium*), the resting sporangium is known to be produced by the conjugation of two individuals. In the Ancylistaceae, where the oogonium and antheridium are differentiated, the sexual reproduction is no more doubted. In the formation of the resting sporangium in *Olpidiopsis* and in the Cladochytriaceae, a similar process is already reported, but it is still doubted if it can be taken as a true sexuality. BALLY'S ('11) cytological study on *Urophlyctis* (included, according to FISCHER, '92, p. 134, in the Cladochytriaceae) has given evidence against the sexuality. Except in *Polyphagus* (DANGEARD, '00; WAGER, '99), the sexual process in the Chytridiales has not been confirmed with cytological evidences, and consequently the real nuclear phase in the sexual product remains still obscure. An attempt especially made towards this point by LOEWENTHAL ('05) on *Zygorhizidium* and by GRIGGS ('10) on *Monochytrium* was unsuccessful in confirming the karyogamy in the resting sporangium produced by the conjugation of two individuals.

The copulation of zoospores (isogametes) I have described in the foregoing may be considered as the simplest and most primitive act of sexuality except the autogamy. Such a case is well known in the unicellular algae, but in the fungi it has remained uncertain. In the present investigation, I have confirmed this fact in a species of the lowest fungi, being able to observe the serial stages of its whole life-cycle both in fresh material and in microtome sections. At present, therefore, there can be little doubt of the fact that the motile isogamete copulation takes the part of the true sexual reproduction in the fungus group.

Admitting now the older observations of FISCH and SOROKIN aright, and



even including the fact given by GRIGGS on *Monochytrium* in the same category, the occurrence of isogamete in the Chytridiales should be considered as an exceedingly rare case. It might perhaps be possible to find an additional instance, if we recall our attention towards the behaviour of the zoospore and the cytology of the resting sporangium of other species or genera in the same fungus group. Yet I do not wish to generalise that the resting sporangium of all *Olpidium* species is the product of sexual process, since the sexuality here is too primitive and rather of a labile nature. Without any morphological differentiation the zoospores can become gametes when conditions admit, otherwise they can ensure the further development asexually. It may be conceived that among numerous species embraced in the same genus of the lower Chytridiales there develops a specific difference regarding the zoospore copulation; for instance, in *Olpidium Viciae* and *Chytridium Mesocarpi* (according to FISCH), the zoospores are liable to copulate, while those in other members of the same genera do not show such property. This is true in the similarly organized algae; in *Chlorochytrium Lemnæ* all the zoospores become the gametes, while in *C. Knyamum* they all develop into sporangia without copulation (see LOTSY, p. 32). Therefore, it is a not impossible conjecture that *Olpidium Viciae* may be the representative of the genus, in which the first stage of the sexual differentiation is manifested.

Having ascertained in the Olpidiaceae the occurrence of the primitive sexual process quite similar to that universally met with in the lower algae, we shall now attempt to consider shortly how much this fact can contribute to our knowledge on the phylogeny of the Chytridiales. With regard to some higher forms of this class of fungi the phylogenetic relationship has recently been discussed by ATKINSON ('09) and PETERSEN ('10) at full length. As I have not here any evidence to defend, or oppose, either of their arguments, the consideration shall be confined to the lower forms, namely the Olpidiaceae.

Relating to the origin of the Chytridiales as a whole and its affinity to the other Phycomycetes, the simple and non-mycelial vegetative body and the absence of the sexual organs in most species have induced competent authors to develop quite opposed theories, each supported by several reasons.

but not, of course, by a direct proof. Of older publications we see some authors (DE BARY, '84; BREFELD, '89) cling to the view that Chytridiales is a retrograde form from the mycelial fungi or the algae, while some (FISCHER, '92; DANGEARD, '01) stand against them maintaining that it has developed along a progressive line of evolution. At present, the problem offers still an open field for discussion, and the opinions recently advanced defend one or the other theory; thus LOTSY, VUILLEMIN ('08), and ATKINSON ('09b) the latter, while PETERSEN ('10) the former theory. The one point of more importance than what has been looked upon by these authors as the basis of their theories is the development of the most primitive sexuality in the Olpidiaceae. The absence of sexual organs in most of this family cannot be ascribed to their degeneration through the debasing influence of parasitism, since we can recognize in *O. Viciae* the evolution of the sexuality. In the algae such a sexual process has been acknowledged as its first developmental stage instead of a degenerated one, and as performed by those algae which are in the lowest rank of their progressive phylogenetic series. Perhaps nothing can be more convincing in studying the problem set forth than the evidence on the sexual process, and the discovery of sexuality in *O. Viciae* gives a clue to the phylogenetic position of the lower fungi.

The simpler forms of the Chytridiales present a close resemblance with certain lower algae (LOTSY'S Endosphaeraceae). However, the resemblance we have so far recognized is concerned with the vegetative body and the asexual reproductive phase. Now we can emphasize it with the evidence of the more important point, the sexual phase. Attaching much weight to this phase, *Olpidium Viciae* may be compared with some interest with *Phyllobium*, *Rhodochytrium*, *Endosphaera*, and *Chlorochytrium*, all belonging to the Endosphaeraceae (LOTSY, p. 32) and all possessing planogametes. Of these, *Phyllobium* has a mycelium-like body and a certain differentiation occurs between the gametes, the one being larger than the other. Therefore, this alga is more highly organized than the *Olpidium*. *Rhodochytrium* (LAGERHEIM, '93; ATKINSON, '08) which bears a close affinity to *Phyllobium* resembles the *Olpidium* especially in the behaviour of the zoospores. They copulate to form the motile zygote, but they can also develop, as in the *Olpidium*, into the zoosporangium without copulation. Though it has been ranged in the

algae, its parasitic habit, losing chlorophyll, excludes the distinction from the fungi, leading some authors to take it as a fungus (LORSY, p. 38) or as marking a transition to the fungi (LAGERHEIM, '93). A slight difference in the morphology between *Rhodochytrium* and *Olpidium* lies on the rhizoid-like body of the former. The organization of this alga may be therefore considered as more advanced than *Olpidium*. With respect to the morphology and both sexual and asexual reproduction, *Endosphaera* agrees well with *Olpidium*, except that in the former the coenobium is formed, by which it claims higher rank than the fungus compared. A closer resemblance is exhibited by *Chlorochytrium*, not only in its vegetative body but especially in the behaviour of the zoospores and gametes. But in this alga the sexual and asexual reproduction is at present considered to be performed separately by different species, the one producing only the gametangium (*C. Lemnae*), while the other only the zoosporangium (*C. Knyazum*). Thus, in the whole aspect, we cannot find a strict accordance of *Olpidium Viciae* with any of the algae above referred to, but it is clear that their general mode of development is quite similar. We may consider that *Rhodochytrium* is a form of the algae resembling most closely the lower Chytridiales, while in turn *Olpidium Viciae* is a representative of the Chytridiales showing many points of resemblance with the lower algae.

A certain similarity can be seen in the life-cycle of *Olpidium Viciae* and *Chlamydomonas* which is considered as the ancestor of the Endosphaeraceae. In both, the motile and non-motile stages are distinguished. The motile individual goes itself into the non-motile form which aids in the multiplication of individuals. Two motile ones fuse together and perform the same process. In *Chlamydomonas* the vegetative period is represented by the motile stage, while it is shown in *Olpidium Viciae* by the non-motile stage. *Polytoma*, being a colourless *Chlamydomonas*, makes the resemblance of the two groups still greater.

From the above considerations it might appear that *Olpidium* has been derived from the Endosphaeraceae or *Chlamydomonas*. But the number of the cilia and the cytological features ought to be considered decisive for this view. These algae are all biciliate and *Olpidium* is uniciliate. As to how much weight can be attached to the number of the cilia on the



phylogenetic problem is a disputed matter. According to LOTSÝ (p. 111), the biciliate and uniciliate form of the Chytridiales constitute probably distinct lines of evolution. In VUILLEMIN'S review ('08, p. 106), who agrees with LOTSÝ, we see that the number of the cilia may be possibly inconstant in members of the same genus, according to different habits. For this reason ATKINSON ('09b) discussed, supported by his own observations, the inadequacy of the principle of classification of fungi based on the number of the cilia, while PETERSEN ('10) acknowledges nevertheless the correctness of this method of classification with respect to the Chytridiales. If we accept LOTSÝ'S view, the phylogenetic connection of *Olpidium* with the above named green algae cannot be maintained, while ATKINSON'S argument does no violence to it. Therefore, taking the number of the cilia out of consideration, the resemblance we have considered may be in favour of the long prevailing view that Chytridiales is derived partly from Protococcales. But this is by no means an unavoidable conclusion. The resemblance may lead us to another assumption. The Endosphaeraceae as well as *Chlamydomonas* stand at the lowest rank in the green algae, so also *Olpidium* in the fungi. It is then possible to conceive, if we assume both series of the fungi and the algae to have descended from a common ancestor, that the close resemblance manifested in the vegetative and reproductive phase of plants occupying the lowest rank of different series may be a natural consequence, because of their being at the first step of divergence of two series and at the least differentiated state from the ancestor. LOTSÝ ('07) pronounced that *Protomastigina* (Senn) has derived the Flagellata, the above named algae through the Polyblepharidae, certain members of the fungi, and others, in different lines of evolution. In consideration of the phylogenetic position of *Olpidium* I come to agree with him. In the Protomastigineae are embraced forms with different numbers of the cilium. *Olpidium* might have derived from the uniciliate form and the algae mentioned from the biciliate form allied to the former. The presence of the sexual reproduction in the Flagellata (PROWAZEK, '07; HAASE, '10) gives evidence for the fact of the parallel evolution of sexuality in three different lines, namely the Flagellata, the fungi, and the Isocontae group of the algae. It is noticeable that a somewhat similar life-cycle and organization as in *Olpidium Viciae* may



be presented in some Rhizomastigaceae (GOLDSCHMIDT, '07) which bear a close affinity to the Protomastigineae, revealing the fact that parallelism in evolution can be seen in these lower animals and plants.

As to the cytological feature, the similarity or dissimilarity in *Olpidium* and the Endosphaeraceae cannot be decided, as the latter does not up to date afford any reliable evidence. Referring, however, to the Protozoa the cytology of *Olpidium* finds certain homologous points. Also the cytological study on other Chytridiales and the Plasmodiophoraceae yields similar results.

From what follows it may be stated that *Olpidium* retains the nuclear characters of the lower Protozoa but its organization coincides remarkably with that of the lower algae. This is in favour of the view that the origin of *Olpidium* is at the level below the Isocontae, its ancestor being allied to that of this algae group among the Protomastigineae.

With this statement the arguments of ATKINSON ('09b) advanced as to the phylogenetic relationship of the Phyeomycetes can be extended further down among the Chytridiales itself, upon which he did not lay much stress. He maintains (p. 468) the existence of a natural series from the Chytridiales to the Oomycetes and Zygomycetes, showing the progressive evolution of the vegetative body and sexual process, instead of their being derived from the confervoid or siphonaceous algae. Though BUTLER ('11), in studying a new aquatic fungus *Allomyces* belonging to the Leptomitaceae, comes to the view that this fungus family has perhaps been derived through forms resembling *Monoblepharis* from the Siphonaceae among the green algae, the main line along which the fungi have developed may be, in my opinion, such as maintained by ATKINSON. In the Chytridiales several stages in the differentiation of the vegetative body, from the non-mycelial to the mycelial, and of the sexual process, from the motile isogamous to the heterogamous, show the possibility of existence of the progressive evolution in its own series and are rather the evidence for the parallel evolution with the green algae.

I cannot enter into details on the problem whether the members of the primitive fungi now included in the Olpidiaceae and Synchytriaceae<sup>1</sup> show a

1. Olpidiaceae: *Reessia*, *Sphaerita*, *Monochytrium*, *Olpidium*, *Olpidiopsis*, *Pseudolpidium*, *Pleotracheus*, *Ectrogella*, *Pleolpidium*; Synchytriaceae: *Synchytrium*, *Woronina*, *Rhizomyxa*, *Rozella*, *Chrysophlyctis*, *Sorolpidium*, etc.

genetic connection among themselves, or whether they have been all derived from still lower organisms. Relating to the latter view a question may arise as to whether their origin is monophyletic or polyphyletic. *Sphaerita* has for a long time been considered as bearing an affinity with the Monadinac zoosporae which are placed by zoologists among the Rhizopods. According to MAIRE and TISON ('11), *Ligniera*, belonging to the Plasmodiophoraceae, is closely allied to *Rhizomyxa* and *Woronina* of the Chytridiales. NEMEC's *Sorolpidium* may connect in a similar manner the two plant groups. The cytology of *Synchytrium* (including BALLY's *Chrysophlyctis*) is divergent from that of the other Chytridiales as studied up to date. Therefore, it may be that the non-mycelial lower Chytridiales embrace forms of heterogeneous origin.

As we have already remarked, *Olpidium simulans* and *Monochytrium stevensianum* show, in the state hitherto investigated, respective resemblance with *Olpidium Viciae*. It leads us to speculate, presuming the further coincidence in points left untouched in the former two with the latter, that the description of *O. simulans* and *M. stevensianum* represents perhaps different phases of two species belonging to the same genus, if not one and the same species. A markedly similar habit of these fungi, occurring on the Compositae in company with other parasites, the former with *Synchytrium* and the latter with *Rhodochytrium*, recalls our special attention and renders it desirable to submit them to a further examination. Although *Olpidium Viciae* resembles in the main either of them, the diversity of their host, the Leguminosae in the former and the Compositae in the latter, keeps us from reducing the three species into a single one, until evidenced by the reciprocal infection experiment and further comparative studies.

On closing I remark that the announcement of the zoospore copulation set forth in the present article is by no means a misleading conclusion arrived at from an inaccurate observation such as based on certain Infusoria or the zoospores of other organisms. On such a misapprehension we may be disposed to fall in treating the aquatic organisms, and the result might be subjected to a severe criticism, were the material not originated from the

pure culture. In the present case, I have convinced myself of the correctness of the result, since it has been drawn from a 1—2 hours' observation under the microscope from the beginning of the liberation of zoospores to the infection of the zygote, during which interval there was no other free-swimming organism liberated in the medium that may be confounded with the zoospore of *Olpidium Viciae*. Further I conclude that the copulation is a quite normal behaviour of the zoospores in relation to the development of the fungus. With this view I do not doubt the justness of EISCH's observation, and I anticipate that a careful study on the Chytridiales will give an additional instance of this sexual act. The discovery of a single young resting sporangium at the binucleate state will be more convincing of this fact than an exhaustive study in observing the actual copulation with not abundant zoospores.

### X. Summary.

1. In *Olpidium Viciae*, some of the zoospores become planogametes and form by copulation the motile zygotes. The zygote behaves quite similarly as an asexual zoospore up to a certain stage of the endophytic development. There is no morphological difference either between the asexual zoospore and the planogamete or between the gametes themselves (isogametes).

2. Copulation may take place even between the zoospores derived from the same sporangium. It does not depend directly upon the external conditions in the medium, but chiefly on the internal conditions under which the zoosporangium is put during the formation of the zoospores. Perhaps it is connected with an unfavourable condition of nutrition in the sporangium.

3. The mode of infection both of the asexual zoospore and the zygote is in agreement with that presented by most of the Chytridiales.

4. Vegetative bodies derived from the zoospores develop into zoosporangia. Under favourable conditions they mature in 5 days after infection.

5. Zoosporangia tend to grow so as to fill up the host-cells. The short exit tube is single or numerous according to the size of the sporangium. It is produced on the centre of a lens-like swollen portion of the sporangium wall. The opening is due partly to its gelatinization and partly to the



osmotic pressure prevailing inside the sporangium. The early opening discharges the immovable spores massed in front of the mouth, while the later opening liberates the immediately swimming spores. The sporangium wall consists partly of cellulose.

6. The final fashioning of the zoospores takes place after the mature sporangium is supplied with water. It is shown by the changes in structure of the sporangium contents lasting 5—10 minutes.

7. The nuclei of the sporangium multiply during the vegetative phase by an amitotic-like division and during the reproductive phase by mitosis.

8. The zygotes develop into resting sporangia. The zygote formation may be found among the zoospores, derived at the first period of the vegetative season from the wintering resting sporangium. However, it takes place predominantly in the later periods.

9. The resting sporangium is binucleate throughout the developmental stage. Attaining to the maximal growth and while precipitating the exospore, each nucleus makes buddings by a peculiar process. The budded portions are soon obliterated, throwing off their contents into the central vacuole of the sporangium. The subsequent uniform distribution of these nuclear substances in the cytoplasm makes the sporangium deeply stainable, reminding us of the chromidial stage.

10. Throughout the resting period the resting sporangium is binucleate. Fusion of the nuclei takes place shortly before the germination. The reduction division in the zygote nucleus thus formed is highly probable. The zoospores derived from the resting sporangium are quite similar morphologically to those from the zoosporangium.

11. The copulation of the motile isogametes in the Olpidiaceae is an evidence for the view that the Chytridiales are not a degenerated form but form the lowest class in the progressive phylogenetic series of the fungi.

12. In the morphology of the vegetative organ, the labile nature of the zoospore copulation, the formation of the motile zygote, and the mode of infection of the encysted zoospore and zygote, *Olpidium Viciae* coincides well with some of the Endosphaeraceae. The number of the cilia is different in both. In cytological respects the fungus shows a certain resemblance with the Protozoa or the Plasmodiophoraceae. These facts may induce the opinion



that the Olpidiaceae, or at least *Olpidium*, have derived from an ancestor below the level of the algae, perhaps in common with the latter.

### Postscript.

The manuscript of the present paper was ready for the press, when two interesting papers, both having more or less bearing upon the present work, arrived almost concurrently to my hand, one from England and the other from America. In the first paper, entitled "Development and sexuality of some species of *Olpidiopsis* (Cornu) Fischer" (*Ann. of Bot.*, Vol. XXVI, No. CI, January, 1912, p. 209), J. T. BARRETT describes at certain lengths the cytology of the zoosporangium and the resting spore (oospore). He concludes that "true sexuality probably exists", taking place by "a supposed fusion of nuclei". This disagrees with BALLY's conclusion on the nuclear feature of the similarly formed resting spore of *Urophlyctis*. We learn from his work that *Olpidiopsis* is cytologically divergent from other members of the Olpidiaceae, making it unnatural to include the fungus in this family. In the second paper, "The development and cytology of *Rhodochytrium*" (*Bot. Gaz.*, Vol. LIII, No. 2, 1912, p. 127), GRIGGS gives the cytology of a fungus-like alga at full length. He points out clearly striking cytological resemblances between *Rhodochytrium* and *Synchytrium*. The comparison of *Olpidium* and *Rhodochytrium* in respect to the nuclear features in the sexual process would have revealed certain interesting facts, had he been able to give more detailed accounts of the resting spore. From his results we may say that the Endosphaeraceae are monoenergid, and this gives an evidence for our view that *Olpidium* bears no direct phylogenetic connection with this family of algae. It is fortunate that the general remarks given in my present paper are not invalidated, but rather are supported, by the facts found by these writers.

March, 1912.

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EXPLANATION OF PLATES.

PLATE XV.

- All figures except Fig. 37 were drawn from the fresh material.
- Fig. 1. Zoospores.  $\times 800$ .
- Fig. 2. Abnormal zoospores.  $\times 800$ .
- Fig. 3. The same.  $\times 800$ .
- Fig. 4. Successive stages of disintegration of a zoospore.  $\times 800$ .
- Fig. 5. Zoospores stopped from swimming for encystation.  $\times 800$ .
- Fig. 6. Encysting zoospore.  $\times 800$ .
- Fig. 7. Encysted zoospore.  $\times 800$ .
- Fig. 8. Encysted zoospore on a slide with the shrunken content.  $\times 800$ .
- Fig. 9. Zoospores in creeping movement.  $\times 800$ .
- Fig. 10. Zoospores come in contact for copulation.  $\times 800$ .
- Fig. 11. Zoospores in fusion.  $\times 800$ .
- Fig. 12. Zygotes just formed, creeping over the substratum in amoeboid movement.  $\times 800$ .
- Fig. 13. Zygotes rounding off for swimming.  $\times 800$ .
- Fig. 14. Zygotes in swimming movement.  $\times 800$ .
- Fig. 15. Zygote coming to rest.  $\times 800$ .
- Fig. 16. Zygotes becoming again amoeboid.  $\times 800$ .
- Fig. 17. Zygote beginning to swim.  $\times 800$ .
- Fig. 18. Zygote coming to final rest.  $\times 800$ .
- Fig. 19. Encysting zygote.  $\times 800$ .
- Fig. 20. Encysted zygotes.  $\times 800$ .
- Fig. 21. Encysted zygotes upon a slide with the shrunken content (about two hours after encystation).  $\times 800$ .
- Fig. 22. Infection of the zygote on the host-cell. *a*, infection tube is formed; *b*, plasm begins



to migrate; *c*, migrated plasms attaches to the tube; *d*, plasms freed from the zygote wall.  $\times 800$ .

Fig. 23. Germinating zygotes producing long tubes.  $\times 800$ .

Fig. 24. Surface view of a host-cell with infecting and infected fungus bodies. *a*, cyst wall and the fungus body migrated from.  $\times 800$ .

Figs. 25-40. Development of the zoosporangium.

Fig. 25. Two host-cells with youngest fungus bodies attached to the nuclei (18 hours after infection).  $\times 300$ .

Fig. 26. Host nuclei and the fungus bodies attached to them (a day after infection).  $\times 300$ .

Fig. 27. Host-cells with the fungus bodies more advanced in growth (2 days after infection).  $\times 300$ .

Fig. 28. Later stages.  $\times 300$ .

Fig. 29. A fungus body two days older than in Fig. 28.  $\times 300$ .

Fig. 30. A full grown zoosporangium and a young resting sporangium, both derived from the spores infected at the same time.  $\times 300$ .

Fig. 31. A single large and still immature zoosporangium, and small aggregated mature sporangia loosely arranged, all infected at the same time. The host-cells of the latter are turned brownish.  $\times 300$ .

Fig. 32. Surface view of a diseased spot. *a*, zoosporangium with reticulate plasms; *b*, zoosporangium with homogeneous plasms; *c*, fashioning of zoospores; *d*, liberation of zoospores; *e*, nearly adult resting sporangium; *f*, healthy host-cell.  $\times 300$ .

Fig. 33. Infection on adult epidermis (surface view), one cell containing a full grown zoosporangium and the other two containing emptied zoosporangia.  $\times 300$ .

Fig. 34. Surface view of a swollen epidermal cell containing a large zoosporangium. Five beaks are formed on the exposed surface of the host-cell.  $\times 300$ .

Fig. 35. Small aggregated emptied zoosporangia in a swollen host-cell (surface view), each with a single beak.  $\times 300$ .

Fig. 36. Aggregated emptied zoosporangia compactly packed in the host-cell (more than 20 in number).  $\times 300$ .

Fig. 37. Formation of the beak. Its apex dissolves partly the wall of the host-cell (microtome section).  $\times 800$ .

Fig. 38. Appearance of two beaks outside the host-cell.  $\times 800$ .

Figs. 39, 40. Swollen beaks about to rupture.  $\times 800$ .

Fig. 41. Young resting sporangia.  $\times 300$ .

Fig. 42. The same, one day older than the zoosporangia shown in Fig. 28.  $\times 300$ .

Fig. 43. The same more advanced in growth.  $\times 300$ .

Fig. 44. Adult resting sporangia.  $\times 300$ .

Fig. 45. Resting sporangium examined in winter.  $\times 800$ .

Fig. 46. The same examined in spring.  $\times 800$ .

Fig. 47. Germinating sporangium, showing the dissolution of the outer layer of the endospore. *a*, formation of the beak on the endospore (stained with gentian violet).  $\times 800$ .

Fig. 48. Sporangium discharging the zoospores.  $\times 800$ .

Fig. 49. Emptied sporangium in a dead host-cell.  $\times 800$ .

Fig. 50. A heap of abnormal cells on the stem.

Fig. 51. Transverse section of a leaf through the diseased spot.

#### PLATE XVI.

##### *Zoosporangium.*

Fig. 1. A host-cell with a single fungus body (one day after infection; compare Pl. XV, Fig. 26).  $\times 900$ .

Fig. 2. Numerous fungus bodies at the same stage, adhering to the host nucleus.  $\times 900$ .

Fig. 3. Binucleate stage of the fungus bodies.  $\times 900$ .

Figs. 4, 5. Four-nucleate stage.  $\times 900$ .

Figs. 6-8. Further growing stages with increasing number of nuclei.  $\times 900$ .

Fig. 9. A zoosporangium and a resting sporangium in the same host-cell and growing at the same rate.  $\times 900$ .

Fig. 10. Premature zoosporangia going to produce the zoospores without passing through the reticulate stage of cytoplasm.  $\times 900$ .

Fig. 11. Further stage of the zoosporangium shown in Fig. 9.  $\times 900$ .

Figs. 12-13. Succeding stages developing a central vacuole.  $\times 900$ .

Fig. 14. Nuclei from the zoosporangium at the same stage, showing the dividing stages.  $\times 2700$ .

Fig. 15. A pair of daughter nuclei from a sporangium at the similar stage.  $\times 2700$ .

Fig. 16. Nuclei at the resting condition.  $\times 2700$ .

Fig. 17. Zoosporangium more advanced in growth than in Fig. 13; central vacuole disappears and the cytoplasm becomes reticulate.  $\times 900$ .

Fig. 18. Further stage of the zoosporangium producing the sporangium wall.  $\times 900$ .

Fig. 19. Zoosporangium approaching maturity, having formed a distinct wall and a beak on it. The nuclei are at the spindle stage.  $\times 900$ .

Fig. 20. Zoosporangium at the next stage; zoospore nuclei are already formed.  $\times 900$ .

Fig. 21. Fashioning of the zoospores.  $\times 900$ .

Fig. 22. Nuclei from the zoosporangium shown in Fig. 18, perhaps at the early prophase  $\times 2700$ .

Fig. 23. Nuclei from a zoosporangium at a similar stage.  $\times 2700$ .

Fig. 24. Spindles from the zoosporangium shown in Fig. 19.  $\times 2700$ .

Fig. 25. A portion of Fig. 20 magnified.  $\times 2700$ .

Fig. 26. A portion of Fig. 21  $\times 2700$ .

#### PLATE XVII.

##### *Resting Sporangium.*

Figs. 1-5. Younger stages of resting sporangia.  $\times 900$ .

Fig. 6. Gamete nuclei from the sporangium shown in Fig. 5.  $\times 2700$ .

Fig. 7. A full grown sporangium with exospore, showing the beginning of the extrusion process in the nuclei.  $\times 900$ .

Fig. 8. The same, showing the nuclei in budding.  $\times 900$ .

Fig. 9. The same, showing the nuclei more advanced in budding.  $\times 900$ .

Fig. 10. Gamete nucleus at the stage of budding.  $\times 2700$ .

Fig. 11. Sporangium in which the budded portion of one nucleus remains intact and that of the other nucleus disorganizes.  $\times 900$ .

Fig. 12. The same at the similar stage.  $\times 900$ .

Figs. 13-14. Sporangia in which the extruded nuclear substances are thrown off in the central vacuole.  $\times 900$ .

Fig. 15. Further stage of the same with the nuclear substances arranged in a reticulum.  $\times 900$ .

Fig. 16. Sporangium, showing the decreasing of the central vacuole in size and the dispersing of the nuclear substances in the cytoplasm.  $\times 900$ .

Fig. 17. Sporangium approaching the adult stage, producing the endo- and exospore. The nuclear substances are still found in the central vacuole.  $\times 900$ .

Fig. 18. An adult sporangium with the compact cytoplasm; the nuclear substances are distributed uniformly throughout.  $\times 900$ .

Fig. 19. Sporangium in wintering condition (January 11, 1908).  $\times 1800$ .

Fig. 20. The same shortly before germination (April 9, 1908).  $\times 1800$ .

Fig. 21. Approach of two gamete nuclei.  $\times 1800$ .

Figs. 22, 23. Zygote nuclei.  $\times 1800$ .

Fig. 24. Zygote nucleus, showing perhaps the synapsis stage.  $\times 1800$ .

Fig. 25. Prophase stage of the zygote nucleus.  $\times 1800$ .

Fig. 26. Later anaphase stage of the same (?).  $\times 1800$ .

Fig. 27. Daughter nuclei just formed from the zygote nucleus.  $\times 1800$ .

Figs. 28-29. Daughter nuclei at the metaphase stage. Spindle fibres are obscure.  $\times 1800$ .

Fig. 30. Four-nucleate stage of the germinating sporangium; the one nucleus at the dividing stage and the one finishing the division.  $\times 1800$ .

Fig. 31. Sporangium with four pairs of daughter nuclei just formed. The nuclei are represented by stellate nucleoli.  $\times 1800$ .

Fig. 32. Differentiation of chromatin granules from the nucleoli.  $\times 1800$ .

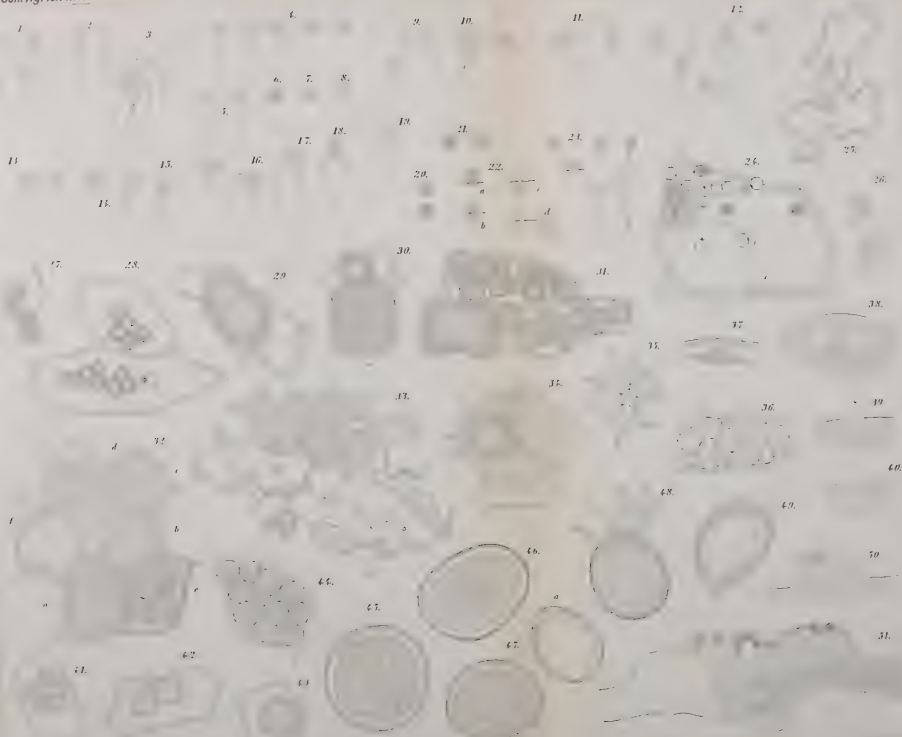
Fig. 33. The nuclei at the resting condition.  $\times 1800$ .

Fig. 34. Sporangium with innumerable nuclei perhaps at a certain dividing stage.  $\times 1800$ .

Fig. 35. Later stage of the germinating sporangium with innumerable resting nuclei; perhaps the stage shortly before the fashioning of the zoospores.  $\times 1800$ .

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# Studien über den anatomischen Bau des Holzes der japanischen Nadelbäume.

VON

M. Fujioka.

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Mit Taf. XVIII—XXIV.

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## Vorwort.

Übung und Erfahrung sind zur Erkennung der Hölzer von der grössten Bedeutung. Wer stets mit Hölzern zu tun hat, ist daher im stande, bloss dem äusseren Aussehen nach die meisten richtig zu bestimmen, was in der Tat mit Leichtigkeit geschehen kann, wenn die Anzahl der zu behandelnden Hölzer nur gering ist. Je grösser die Anzahl der zu bestimmenden Hölzer wird, desto schwieriger wird dieses Bestimmen sein. Für unsere Forstleute und Holzkonsumenten, die die Hölzer von recht mannigfaltiger Art richtig unterscheiden müssen, ist es fast unmöglich, sich bei diesem Bestimmen nur auf das blosse Aussehen zu verlassen, wenn auch die Nadelbaumhölzer ihrem Gefüge nach, wie Farbe, Geruch, Glanz und Jahresringbreite im normalen Zustande teilweise erkannt werden können. Daher müssen wir dabei ausser der Textur noch möglichst viele andere Merkmale in Rechnung tragen, obwohl dieselben nicht immer absolut entscheidend und auch nicht immer leicht wahrnehmbar sind. Von diesem Standpunkt aus können viele technische Eigenschaften zum Zwecke der Erkennung dienen; auch die Farbe der Lösung, welche man aus dem Holz durch Behandlung mit heissem Wasser oder mit anderen siedenden chemischen Flüssigkeiten bekommen wird, oder sogar das Brennen der Hölzer kann zu Hilfe gezogen werden. Das Bestimmen unter dem Mikroskop, wenn es auch aus naheliegenden

Gründen durch Forstleute nicht immer ohne weiteres ausgeführt werden kann, liefert uns jedoch die reelle Grundlage zur Erkennung; und wenn man mit einiger Übung die meisten Arten ohne Mikroskop viel einfacher und leichter als mit demselben bestimmen kann, muss dennoch natürlich die auf anatomischer Grundlage gegründete Unterscheidung als die sicherste Methode bezeichnet werden. Ferner kann die Verfälschung sicher nur mit Hilfe der Anatomie entdeckt werden, da dann fast immer nur ein kleines Stück zur Verfügung steht. Die anatomische Erforschung der Hölzer ist nicht nur zum Bestimmen, sondern auch in vielen anderen Beziehungen unentbehrlich. Prof. Dr. NÖRDLINGER betont in seinen Werke: „Da das Holz nach drei Richtungen verschieden gebaut ist, vermögen wir ohne Kenntnis des anatomischen Baues auch die Festigkeitserscheinungen nicht zu erklären.“ Auch Prof. Dr. MAYR sagt: „Sicher sind die sich in physikalischen und technischen Eigenschaften darstellenden Verschiedenheiten der Hölzer zum grossen Teile in den anatomischen Verhältnissen begründet, ob die Anatomie zur Aufhellung der mikellaren und molekularen Struktur der Zellhülle, deren Bedeutung für das chemische, physikalische und technische Verhalten der Holzwandung überhaupt noch ganz im unerforschten Dunkel liegt.“ In der Tat bildet die Kenntnis der Holzanatomie die Hauptbedingung zum Erforschen, nicht nur der Festigkeit, sondern auch der anderen allgemeinen Eigenschaften der Hölzer.

Aus diesem Grunde habe ich die histologische Untersuchung der Hölzer nebst deren makroskopischer Bestimmung vorgenommen. Diesbezüglich hat aber Herr Dr. Y. NAKAMURA vor langer Zeit eine Arbeit veröffentlicht, die leider nur wenige Arten umfasst und, mir einige Unrichtigkeiten zu enthalten scheint. Meine vorliegende Arbeit bezweckt mithin die Ergänzung und Berichtigung jener. Infolge des Fehlens von Proben habe ich einige Arten, d. h. *Biota orientalis*, *Keteleeria Davidiana* var. *formosana*, *Taiwania cryptomerioides*, etc. nicht untersuchen können, die allerdings forstlich von ganz geringer Bedeutung sein dürften.

Was die Methode der Anfertigung der Dauerpräparate anlangt, so kochte ich zuerst kleine Würfel der Materialien mit Ausschluss des Zweiges<sup>1</sup> über 24 Stunden in Wasser. Dadurch wurde das Holz etwas erweicht und schnitt-

1. Grüne Materialien wurden frisch geschnitten.



fähig gemacht. Diese Würfel behandelte ich dann mit Hydrofluorsäure, die vor dem Schneiden durch Auswaschen mit Wasser wieder entfernt werden musste. Wenn auch die Konzentration dieser Säure und die Dauer der Einwirkung natürlich nach der Natur der betreffenden Objekte variabel sind, so habe ich im Allgemeinen die Hölzer in 30% Säure etwa 2 Monate lang liegen lassen. Das Auswaschen dieser Säure durch Wasser bedarf mehrerer Stunden, doch kann man dies durch Kochen of tsehr beschleunigen. Diese Materialien habe ich vorher in ein Gemisch von 1 Teil 90% Alkohol und 1 Teil Glycerin gebracht. Zum Schneiden gebrauchte ich einfach ein gewöhnliches Rasirmesser und zur Entfernung der Luft bediente ich mich einer Wasserstrahlpumpe, was für die Untersuchung der Radialschnitte besonders erforderlich war. Ich legte dabei die Schnitte in einem Probierrohr derartig, dass sie beim Schütteln desselben direkt in die Tinktur (Safranin-Lösung) hineinfallen konnten. Dieses Rohr hängte ich in eine auszupumpende Flasche und nahm es erst wieder heraus, nachdem die Schnitte in der Tinktur gesunken waren. Für die Färbung sind etwa 24 Stunden erforderlich. Beim Übertragen der Schnitte bediente ich mich der gewöhnlichen Übertragungsmethode aus Wasser in Canadabalsam.

Was die Nomenklatur anbetrifft, so schliesse ich mich hauptsächlich Dr. GOTHAN an. Die Zahlenbeispiele über die Zellwandungsdicke sowie die Zahl der Markstrahlzellen am Tangentialschnitt, welche ich unten angebe, sind natürlich nach den Individuen etwas variabel. Die Farbe und der Geruch sind den meisten Nadelbäumen eigentümlich, und man kann oft bloss dadurch die Arten unterscheiden, was aber im Allgemeinen erst nach langer Erfahrung möglich sein dürfte. Die Beschreibung über die Splintholzfärbung ist bei einigen Hölzern weggelassen, wo mir ein Exemplar des Splintes nicht zur Verfügung stand.

Schliesslich möge mir hier gestattet sein, Herrn Prof. Dr. KAWAI meinen herzlichen Dank auszusprechen, da ich unter ihm diese Arbeit begonnen und zu Ende gebracht habe. Herren Prof. Dr. IKENO und KUSANO und Dr. Y. SUZUKI, die mich bei der Ausführung dieser Arbeit—sei es durch gelegentlichen Rat, sei es durch freundliche Anweisung—unterstützt haben, bin ich auch zu besonderem Dank verpflichtet. Andern Herren möchte ich höflichst für Zusendung von Untersuchungsmaterial danken.

## Beschreibung der untersuchten Arten.

### GENKGO BILOBA L. (Ichō).

Das Splintholz ist sehr breit und gelbweiss, während das Kernholz gelblich bis dunkelgelb ist. Die dunkelgefärbte Spätholzschicht geht ganz allmählich in die schwach gefärbte Frühholzschicht über. Die Markstrahlen sind sehr fein, aber deutlich. Das Holz ist meist breitringig, doch manchmal schmalringig. Als besonders ausgeprägte Merkmale dieses Holzes dienen kleine, nur auf der Hirnfläche sichtbare weisse Pünktchen, die fast ebenso aussehen, wie die Harzgänge der Hölzer von *Pinus*-Arten. Näheres darüber unten bei mikroskopischen Befunden. Wegen seiner grossen Dimension und dichter und homogener Textur ist dieses Holz besonders als Wandtafelmaterial hochgeschätzt.

ANATOMISCHER BAU. Das Holz ist makroskopisch wie mikroskopisch leicht erkennbar. Was den anatomischen Bau dieses Holzes anlangt, so besteht es nur aus bald weiten, bald englumigen Tracheiden, deren Wandung im Früh- und Spätholz so gleichmässig ist, dass auf Querschnitt die Jahrringgrenze sich nur durch die etwa in Tangentialrichtung gestreckten englumigen Endzellen erkennen lässt (Fig. 1); dieselbe beträgt im Frühholz ca.  $3-5\mu$  und im Spätholz ca.  $4-5\mu$ . Die kreisrunden Hoftüpfel der Tracheiden sind bei weitlumigen nicht selten zweireihig, und die Poren sind öfters gekreuzt, besonders im Spätholz. Diese Hoftüpfel kommen auch an den Tangentialwänden vor, dabei sind sie nur spärlich an Zahl und viel kleiner als an den Radialwänden. Die Markstrahlen sind 1 bis 11, meist 1 bis 5 zellenhoch. Die den anstossenden Tracheiden angehörigen Markstrahltüpfel sind von rechts oben nach links unten geneigt und beim Frühholz schmal elliptisch, selten mit einem äusserst schmalen Hofe versehen, oder „eiporig.“ Hier betragen sie 2 bis 5 pro Kreuzungsfeld. Im Spätholz sind sie fast schräg-linear und betragen meist 2 pro Feld. Die Zellwandung dieses Strahlparenchyms ist ringsum am dünnsten unter allen unseren Nadelhölzern.

Obwohl die oben erwähnten Merkmale für die Erkennung des *Ginkgo*-Holzes genügen, können wir doch nicht weiter gehen, ohne einige Worte

über die Krystüllschläuche zu sagen—ein besonders entscheidendes Merkmal dieses Holzes. Die Schläuche, welche aus äusserst dünnwandigen, stark gebauchten, meist elliptischen Säcken bestehen, ähneln sehr den Markstrahlen im Querschnitte, sind aber viel grösser (Fig. 2). Auf dem Querschnitt kann man sie dadurch erkennen, dass diese zarten Zellen regellos hier und da zerstreut vorkommen und etwas grösser sind als die umgebenden Tracheiden (Fig. 1). Alle diese Schläuche enthalten im allgemeinen sternförmige Calciumoxalatkrystalle.

PODOCARPUS CHINENSIS Wall. (Maki).

Das Holz ist bräunlichgelb und nach dem Aussehen etwa dem von *Thujopsis dolabrata* ähnlich, was auf die gleichmässige Zerstreung im Holz von die rotbraunen Harzkörnchen enthaltenden Parenchymzellen zurückzuführen ist. Der Übergang des Kernholzes ins Splintholz ist sehr allmählich, und beide sind nicht sehr verschieden. Charakteristisch ist die schmale gelblichweissgraue Frühzone; auf Hirnende zeigt die breite bräunlichgelbe Spätzone nicht selten den halbmondförmigen Zuwachs. Die Jahrringe sind bald schmal, bald breit. Die Markstrahlen sind äusserst fein, zahlreich und gelblich gefärbt. Das Holz ist geradfaserig, gut spaltig und sehr dauerhaft.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden und Holzparenchym. Was die Zellwandverdickung betrifft, so beträgt die des Frühholzes 3-4 $\mu$ , die des Spätholzes 4-5 $\mu$ . Die weit- und englumigen Tracheiden treten in ein und derselben Fröhschicht zusammen (Fig. 3). Nicht selten tritt der Hoftüpfel mit rundlicher Begrenzung und schräg-elliptischem Porus auch an den Tangentialwänden des Frühholzteiles auf (Fig. 4). An den Radialwänden sind dieselben Hoftüpfelpori meist gekreuzt und im Spätholz schräg-schmal-elliptisch. Die Querscheide des Strangparenchymes ist meist fast glatt und horizontal gelegen, nur selten ist sie mit unvollkommenem „Höcker“ versehen. Die sehr zahlreichen Markstrahlen sind einreihig und 1 bis 21, meist 1 bis 14zellig; sie besitzen glatte Horizontal- sowie Tangentialwände, von denen die letzteren besonders dünnwandig sind. Die Markstrahlentüpfel dieses Holzes nennt man kurz „podocarpoide Tüpfel“, wo der Porus im Frühholz schmal-elliptisch und im Spätholz fast linear ist. Bei unseren *Podocarpus*-



Arten ist er aber niemals vertikal gerichtet, sogar im Spätholz etwas geneigt (Fig. 5).

Überdies habe ich bei weitleumigen Tracheiden öfters breitelliptischen Porus beobachtet. Die Zahl der Markstrahltpfkel beträgt im Frühholz 1 oder 2, meist 1 (Innenzelle), und 1 bis 3, meist 2 (Grenzelle), und im Spätholz immer 1 pro Kreuzungsfeld.

#### PODODARPUS NAGEIA R. Br. (Nagi).

Das Holz ist bald schmal-, bald breitringig wie bei *Podocarpus chinensis*. Die Markstrahlen sind ausserordentlich fein. Die Farbe ist der des Holzes von *Thujopsis dolabrata* sehr ähnlich. Die Begrenzung zwischen Früh- und Spätzone ist nicht so scharf wie bei *P. chinensis*; aber im grossen und ganzen ist dieses Holz in allen Beziehungen dem letztgenannten ähnlich.

ANATOMISCHER BAU. Der histologische Bau dieses Holzes stimmt fast mit dem von *P. chinensis* überein. Die Harzparenchyme sind zerstreut, die Querscheiden derselben sind meist fast glatt und schief oder horizontal gelegen. Auf Tangentialschnitt beschränken sich die Hoftüpfel der Tracheiden vorherrschend im Spätholz (nur selten im Frühholz), dabei sind sie meist gekreuzt. Auf Radialschnitt kommen die etwa elliptischen Pori der Hoftüpfel auch meist gekreuzt vor, und die dem Spätholzteile angehörigen schmal-elliptischen bleiben noch etwas geneigt. Die geringe Verschiedenheit in der Zellwandungsdicke zwischen Früh- und Spätholz ist bemerkenswert; sie beträgt im allgemeinen  $2-3\mu$ . Der Dickwandigkeit wegen sind die Horizontalwände des Strahlparenchymes nicht so glatt wie bei der vorigen Art. Die schiefen „podocarpoiden“ Markstrahltpfkel treten im Frühholz in Zahl von je 1 oder 2, meist je 1 (Innenzelle), und je 1 oder 2 (Grenzelle) pro Feld auf, im Spätholz betragen dieselben 1 (Innenzelle) und 1 oder 2 (Grenzelle).

#### CEPHALOTAXUS DRUPACEA S. et Z. (Inugaya).

Das Kernholz fehlt fast ganz. Das Holz ist schwach gelblichweiss, aber nicht selten bräunlichgelb, wenn die Harzparenchymzellen stark entwickelt sind. Die Markstrahlen sind sehr fein, zahlreich und gelblich



wie bei den meisten Nadelbäumen. In Druckholzteile dieses Holzes findet man öfters im Vergleich mit den übrigen Nadelbäumen ein umgekehrtes Verhältnis bei der Färbung innerhalb eines Jahrrings, da die stärkere dunkelbräunliche Färbung in der Frühzone stattfindet. Diese dunklere Färbung geht allmählich in die gelblichweisse Herbstzone über, was der allgemeinen Regel gerade umgekehrt ist (Fig. 9). Das Holz ist mässig hart, von gleichmässigem Gefüge und kann unter unsern Nadelhölzern am glättesten gehobelt werden. Es könnte vielleicht gutes Material für Schmitzereien oder Masstäbeanfertigung liefern.

ANATOMISCHER BAU. Die meist gekreuzten Hoftüpfel kommen an den Radialwänden des Früh- und Spätholzes vor. Die Tracheiden sind verschiedenlumig und so stark verdickt, besonders im Frühholz des gedrückten Teiles, dass die Zellumen rundlich sind. Sehr auffallend ist die stärkere Wandverdickung der Frühholzzellen, wie bei den Spätholzzellen, was bei andern Holzarten niemals der Fall ist (Fig. 7). In der Nähe der Jahrringgrenze beträgt sie im Früh- und Spätholz ca.  $3-4\mu$ . Die Tangentialwände der Breitfasern sind nur sehr selten hofgetüpfelt. Was die „Taxaceen-Spiralen“ dieses Holzes anlangt, so verhalten sie sich wie bei anderen Taxaceen. Überdies führt es immer Harzparenchym, das im Frühholz wie auch im Spätholz zerstreut in grosser Menge vorkommt, was die starke Färbung des Holzes verursacht. Die Markstrahlen sind 1 bis 26, meist 4 bis 16 Zellen hoch und man beobachtet selten zweireihige (Fig. 8). Die Tangentialwände des Strahlparenchyms sind meist dünnwandig und bald schräg, bald senkrecht zur Wandung derselben gelegen; die Horizontalwände derselben sind dickwandig, daher nicht ganz glatt, und zeigen, obwohl spärlich, „lochporige“ Verdickung. Markstrahltüpfel mit schräg, etwa schmal-elliptischem Porus treten im Frühholz, je 1 oder 2, meist je 1 (Innenzelle), und je 1 bis 3, meist je 2 (Grenzzelle), und im Spätholz stets je 1, pro Feld auf.

TORREYA NUCIFERA S. et Z. (Kaya).

Das Holz hat ziemlich breiten, schwach gelblichweissen Splint, welcher sehr allmählich in das gelbe Kernholz übergeht. Die Jahrringe sind schwachwellig. Das Holz ist hart, schmalringig, sehr elastisch, spaltbar, sehr

dauerhaft und wirft sich nicht, aber bildet leicht Luftrisse. Der eigentümliche lang andauernde starke Geruch, welcher durch ätherische Öle verursacht wird, bildet ein ausgeprägtes Merkmal dieses Holzes. Öfters ist es durch punktierte Adventivknospenspuren ausgezeichnet.

ANATOMISCHER BAU. Das Holz besteht nur aus Tracheiden mit je 1 bis 3, meist je 2, bald ganz umgekehrt verlaufenden Spiralen und führt 3, meist je 2, bald keine Harzgänge. Die Zellwandungsdicke beträgt im Frühholz ca.  $3\mu$  und im Spätholz ca.  $3-5\mu$ . Die Markstrahlen sind 2 bis 18, meist 4 bis 9 Zellen hoch. Die Horizontalwände derselben sind etwas dünnwandig, sie zeigen aber selten „lochporige“ Verdickung, wie man auf Quer- oder Radialschnitt erkennen kann. Die Tangentialwände sind äusserst dünnwandig, daher ganz glatt, und meist senkrecht gelegen. Die Markstrahlentüpfel sind geneigt, ebenso wie bei den bisherigen Arten, von rechts nach links, und die rundliche Hofbegrenzung derselben ist etwas deutlicher als der Umriss des schmalelliptischen Innen-Porus, der im Spätholz fast linear ist. Diese Tüpfel kommen im Frühholz zu je 2 (Innenzelle) und je 1 bis 4, meist je 3 (Grenzelle), und im Spätholz zu je 1 oder 2, meist 1 (Innenzelle), und je 1 oder 2, meist 2 (Grenzelle) pro Kreuzungsfeld vor.

#### TAXUS CUSPIDATA S. et Z. (Ichii).

Das Splintholz ist sehr schmal und schwach gelblichweiss. Das dunkelrote Kernholz ist scharf vom Splint begrenzt. Die sehr schmale Spätzone zeichnet sich scharf durch seine dunkle Färbung auf Hirnende, sowie auf Längsfläche ab. Die Markstrahlen sind so fein, dass sie auf Hirnfläche mit freien Augen fast unerkennbar sind. Das Holz ist schmalringig und nimmt schöne Politur an. Wegen des Fehlens der gefärbten Streifen des Holzparenchyms und des angenehmen Geruches kann das Holz von *T. cuspidata* von dem von *Juniperus chinensis* leicht unterschieden werden.

ANATOMISCHER BAU. Das Holz besteht nur aus Tracheiden und hat keine Harzgänge. Die Tracheidenwandung ist im Frühholz ca.  $3\mu$  und im Spätholz ca.  $5\mu$  dick. Die spirale Verdickung der Tracheiden ist gleichmässig verteilt und so auffallend, dass es unmöglich ist sie zu übersehen, in Übereinstimmung mit *Torreya* und *Cephalotaxus*. Diese Taxaceen-Spiralen verlaufen je 1 bis 3,

meist je 2, von links nach rechts; nicht selten kann man in einer und derselben Zelle ganz umgekehrt verlaufende Spiralen beobachten. Die Hoftüpfelung der Tracheiden lässt sich an den Radialwänden des Früh- und Spätholzes erkennen, obwohl sie im letzteren geringer an Zahl, viel kleiner und mit schmalelliptischem Porus versehen ist. Die Tangentialwand der Breittfasern, besonders der Endzellen jedes Jahrrings, ist dagegen niemals hofgetüpfelt. Die zahlreichen Markstrahlen bestehen aus 2 bis 18, meist 5 bis 12, dünnen, daher glatten, stark in der Radialrichtung gestreckten Zellen, deren Tangentialwände bedeutend dünner und meist schräg gelegen sind. Was die Form der Markstrahltüpfel betrifft, so besitzen sie viel breiteren Tüpfelporus, der erst im Spätholz schmal-elliptisch wird. Dieser Tüpfel kommt im Frühholz zu je 1 oder 2, meist je 2 (Innenzelle), und je 3 oder 4 (Grenzzelle), und im Spätholz zu je 1 (Innenzelle) und je 2 (Grenzzelle) pro Feld vor.

*SCIADOPITYS VERTICILLATA* S. et Z. (Kōyamaki).

Das Splintholz ist sehr schmal, weiss, während das Kernholz schwach gelblich ist. Die Markstrahlen sind sehr fein, doch etwas deutlich. Die Jahrringe sind stellenweise grobwellig. Das Holz ist schmalringig, fein- und geradfaserig, gut spaltbar und dauerhaft. Der eigentümliche Geruch zeichnet es leicht aus. Es geschieht nicht selten, dass die Bildung des schwarzbräunlichen Druckholzes durch die ganze Jahrringsbreite geht (Fig. 16).

ANATOMISCHER BAU. Dieses Holz ist sowohl makroskopisch als auch mikroskopisch mit Leichtigkeit erkennbar. Der Übergang vom Spätholz ins Frühholz ist scharf. Es besteht nur aus Tracheiden. An der Tangentialwand des Spätholzes sind zahlreiche spaltförmige, nicht selten gekreuzte Tüpfel vorhanden. Die Radialwand ist sehr reich an Hoftüpfeln, die sogar im Spätholz, wie beim Tangentialschnitt, als schmal-spaltförmig sich erweisen. Die Zellwandungsdicke ist im Frühholz ca.  $3\mu$  und im Spätholz ca.  $6\mu$ . Die Markstrahlen sind niedrig, d. h. 2 bis 9, meist 3 bis 6 Zellen hoch, was das Holz wenig spaltbar machen könnte, doch ist es wirklich aus besonderen Ursachen gut spaltend. Charakteristisch ist für dieses Holz die Perforation der Strahl-



parenchymzellen, deren Wandung äusserst dünn und glatt ist. Verfolgt man auf einem Radialschnitt die Markstrahltüpfel vom Spätholz bis zum Frühholz, so beobachtet man, dass die Tüpfel anfänglich mit senkrecht gerichteten linearen oder schmal-elliptischen Pori versehen sind, dann plötzlich zu den sog. "cupressoiden," d. h. zu solchen mit etwas breit-elliptischen Pori werden. Dabei bleibt zuerst ein ziemlich breiter Hof; aber er nimmt immer an Grösse ab, bis schliesslich der Porus dem Hofe an Grösse gleich wird und sich fast horizontal stellt. Solche hoflose Markstrahltüpfel, sog. „eiporige,“ erinnern an die der Kiefer. Alle diese Markstrahltüpfel treten stets zu je 1 pro Feld (Fig. 15).

CUNNINGHAMIA SINENSIS R. Br. (Kōyōsan).

Der Splint ist gelblichweiss und nicht breit; das Kernholz ist schwach bräunlichweiss. Die Begrenzung zwischen beiden ist nicht scharf. Die Markstrahlen sind fein und deutlich. Das Holz ist zeitweise glänzend und bald breit-, bald schmahringig und mit grobwelligen Jahrringen versehen. Auf Hirnfläche geht die stark gefärbte Spätzone allmählig in die Frühzone über. Die gefärbten kurzen Striche, welche von den Harzparenchymzellen herrühren, sind reichlich vorhanden, sowohl in Spätzone als auch in Frühzone, besonders in ersterer; ausserdem sind oft die Markflecke sichtbar, besonders in der Mitte eines Jahrrings. Das beste Erkennungsmerkmal dieses Holzes besteht darin, dass dasselbe der zahlreichen ganz kleinen Adventivknospenspuren wegen wie punktiert erscheint.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden und Parenchym. Die ersteren, an denen die Hoftüpfelung sogar bei der Tangentialwand des Spätholzes vorhanden ist, sind im Frühholz  $2-3\mu$  und im Spätholz  $3-4\mu$  dick. Das Strangparenchym, dessen Querscheiden fast glatt sind, befindet sich reichlicher in Frühzone als in Spätzone, was bei den anderen stets Holzparenchym führenden Hölzern gerade umgekehrt ist. Wo dieses Strangparenchym reichlich vorhanden ist, bemerkt man, dass die Tracheiden wieder dicker sind als anderorts ( $3-4\mu$ ) (Fig. 17). Die Markstrahlen sind einreihig, sehr selten zweireihig (Fig. 18) und 2 bis 20, meist 5 bis 12 Zellen hoch. Die Zellen derselben sind dünnwandig und glatt, besonders an den Tangentialwänden,



die meistens senkrecht oder nahezu so gelegen sind. Nur ausnahmsweise zeigen die Horizontalwände „lochporige“ Verdickung. Was die Form der Tüpfel betrifft, bemerkt man hier wie bei *Sciadopitys* verschiedene Gestaltübergänge. Die schmal-elliptischen Tüpfelpori der Spätzone werden plötzlich im Frühholz etwas „cupressoid“ und nehmen immer mehr an Grösse zu. Schon bei dünnwandigeren, weitleumigen Zellen entstehen die rundlichen „Fiporen“ („glyptostroboide-Tüpfel“ nach GOTHAN). Die Tüpfel kommen im Frühholz zu je 1 oder 2, meist je 2 (Innenzelle), und je 2 oder 3, meist je 2 (Grenzzelle), und im Spätholz zu je 1 oder 2, meist je 1 (Innenzelle), und je 2 (Grenzzelle) pro Feld vor.

#### CRYPTOMERIA JAPONICA Don. (Sugi).

Das Splintholz ist ziemlich breit und weiss, während das Kernholz nach dem Standorte von bräunlichrot bis dunkelbräunlichrot oder ganz dunkelbraun variiert. Der Übergang zwischen beiden ist scharf. Die Markstrahlen sind kaum oder nur schwer sichtbar. Das Holz ist meist breitringig, zuweilen schmalringig, mittelleicht, geradfaserig, spaltbar, und führt einen eigentümlichen Geruch. Bei diesem Holz ist bemerkenswert, dass die Spätzone noch mässig schmal bleibt und etwas schroff begrenzt ist, wenn auch der Jahrring ziemlich breit ist. Nicht selten ist es dem Holz von *Thuja japonica* ähnlich. Das Unterscheidungsmerkmal ist das reichliche Vorhandensein von feinen gefärbten Strichen.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden sowie Harzparenchym und führt keine Harzgänge. Die Höfe und die Pori an den Tangentialwänden der Tracheiden sind kreisrund. An der Radialwand verhält sich die Grösse der Behöfung zu der der Zellumen wie 1:2. Die Zellwandung ist im Frühholz 2-3 $\mu$  und im Spätholz 5-7 $\mu$  dick. Das Harzparenchym ist weder im Frühholz noch im Spätholz zerstreut vorhanden, sondern an der Tangentiallinie mehr oder weniger gruppenweise angeordnet. Die Querscheide desselben ist meist glatt, sonst regellos verdickt oder mit „Höcker“ versehen. Die Markstrahlen sind 2 bis 22, meist 5 bis 9 Zellen hoch und führen meist durchweg glatte Horizontalwände, die nur selten „lochporig“ verdickt sind. Die Tangentialwände derselben sind viel dünner als bei *Cunninghamia* und

auch ganz glatt. Der „cupressoide“ Tüpfel führt im Frühholz breit-elliptischen Porus, der bei sehr weitleumigen nicht selten fast horizontal gelegen ist (Fig. 20). Im Spätholz wird der Porus allmählich schräg schmalelliptisch, ja in extremen Fällen ist er nahezu senkrecht gerichtet. Diese Tüpfel treten im Frühholz meist zu je 2, und im Spätholz je 1, nur bei Grenzzellen stellenweise zu je 2 pro Feld auf.

#### THUJOPSIS DOLABRATA S. et Z. (Hiba).

Das Splintholz ist schwach gelblichweiss, während das Kernholz dunkel bis schwach graugrünlich ist; aber zwischen beiden lässt sich keine scharfe Begrenzung bemerken. Die schmale Spätzone ist etwas scharf markiert auf Hirnende sowie auf Spiegelfläche. Die Markstrahlen sind äusserst fein und nur schwer sichtbar. Die rötlichbraunen Striche kommen nur selten längs dem Jahrring vor. Das Holz ist gerad- und feinfaserig, zugleich schmalringig, und besitzt einen eigentümlichen schwachen Geruch. Bei Verwendung im feuchten Zustande ist es von grosser Dauer.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden sowie Strangparenchym und hat keinen Harzgang. An der Tangentialwand des Spätholzes befindet sich die kleine Hoftüpfelung. Die Zellwandungsdicke ist im Frühholz  $1-3\mu$  und im Spätholz  $3-4\mu$ . Das Harzparenchym tritt in der Nähe der Spätzone hervor und ordnet sich selten zu mehreren etwa in Tangentialrichtung (Fig. 21). Die Querscheiden desselben sind meist mit „Höcker“ versehen. Die Markstrahlen sind 1 bis 15, meist 4 bis 9 Zellen hoch. Während die bald schräg, bald senkrecht gelegenen Markstrahl-tangentialwände dünnwandig und meist glatt sind, sind die Horizontalwände etwas dicker und nicht ganz glatt, so dass man auf Querschnitt dieses Holzes, obwohl selten, die „lochporigen“ Tüpfel bemerken kann. An der Radialwand kommen die mit schmal-elliptischen, meist aufwärts gerichteten Pori versehenen Markstrahl-tüpfel im Frühholz je 2 oder 3 (Innenzelle) und je 2 bis 5, meist je 3 oder 4 (Grenzzelle), und im Spätholz je 1 oder 2 (Innenzelle) und je 2 (Grenzzelle) pro Feld vor (Fig. 22).

## LIBOCEDRUS MACROLEPIS Benth. (Shōnanboku).

Das Holz ist bräunlichgelb bis schwarzbräunlich und hat wellenförmige Jahrringe. Es ist schmalringig, schwer spaltig, und führt einen eigentümlichen Geruch. Die Möbel aus diesem Holz werden von Insekten gemieden.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden und Harzparenchym. Die ersteren besitzen an den Tangentialwänden des Spätholzes die meist gekreuzten Hoftüpfel. Die breit-elliptischen Pori der Radialwandtüpfelung sind nicht selten gekreuzt. Was die Zellwandverdickung anlangt, zeigt dieses Holz auf Querschnitt einen so undeutlichen Unterschied zwischen Früh- und Spätholz, dass die Jahrringgrenze nur durch die etwaigen, sich in der Tangentialreihe stellenden Breitfasern markiert wird (Fig. 23). Beispielsweise beträgt die Dicke im Frühholz 3-4 $\mu$  und im Spätholz 5-6 $\mu$ . Das Harzparenchym ist in ungeheurer Menge zerstreut vorhanden, und etwa zahlreicher im Spätholz. Die Querscheidewände desselben sind meist mit „Höcker“ versehen. Die an Harz sehr reichen Markstrahlen sind 1 bis 34, meist 4 bis 16 Zellen hoch und selten zweireihig (Fig. 24). Die Wandung desselben ist allseits ziemlich dünnwandig, aber nicht glatt, also zeigen die Horizontalwände stellenweise schwache „lochporige“ Verdickung, oder mindestens die Neigung dazu. Charakteristisch sind die Markstrahlktüpfel, deren Porus auch im Spätholz noch breit genug bleibt (Fig. 25). Im Frühholz hat diese „cupressoide“ Tüpfelung breiten Porus und Hof, und der Porus gleicht, wenn auch selten, an Grösse fast dem letzteren. Diese Tüpfel kommen im Frühholz zu je 1 bis 3, meist je 2 (Innenzelle), und je 3 oder 4 (Grenzzone), und im Spätholz zu je 1 (Innenzelle) und je 1 oder 2 (Grenzzone) pro Kreuzungsfeld vor. Bezüglich des histologischen Baues dieses Holzes sind bemerkenswert das reichliche Vorkommen des mit Harzkörnchen erfüllten Parenchyms und der fast gleichartige Bau des Früh- und Spätholzes.

## THUJA JAPONICA Maxim. (Nezuko).

Das Kernholz ist schwach schwarzbräunlichgrau bis schwach gelbbraunlich, und vom weissen schmalen Splintholz scharf begrenzt. Die sehr



schmale, zuweilen nur fast haardicke Spätzone ist wellenförmig und zeigt schroffen Übergang. Die Markstrahlen sind äusserst fein und fast kaum oder nur schwer erkennbar. Die gefärbten Striche der Holzparenchymzellen sind nur spärlich an Zahl und kommen ganz zerstreut vor. Das Holz ist leicht, schmalringig und feinfaserig.

ANATOMISCHER BAU. *Thuja japonica* besitzt das an Harzparenchym ärmste Holz unter unseren immer Holzparenchym führenden Nadelbäumen. Die Querscheide dieses Parenchymes hat meist 1 bis 4 deutliche „Höcker.“ Die Wandung des Spätholzes, das an der Tangentialwand mit kleinen Hoftüpfeln versehen ist, beträgt ca.  $2-5\mu$ , und jene des Frühholzes  $1-2\mu$ . Die Grösse der Radialwandhöfe verhält sich gegen die Zellumen wie 1:3; also hier sind die Tüpfel relativ kleiner als beim Holz von *Cryptomeria japonica*. Die Markstrahlen sind 1 bis 18, meist 3 bis 7 Zellen hoch. Nicht selten sind die Markstrahlhorizontalwände durch „lochporige“ Verdickung ausgezeichnet. Wenn auch äusserst selten, kann man ausser gewöhnlichen sehr dünnen, daher glatten Tangentialwänden auch solche beobachten, die wie *Juniperus*-Holz mit „Höcker“ versehen sind. Bei der von den beiden Wänden gebildeten Ecke befindet sich eine kleine Vertiefung der Horizontalwände, die da besonders deutlich ist, wo die eine sich mit der anderen senkrecht trifft. Die Markstrahl-tüpfel sind ganz gleich gebildet wie bei *Cryptomeria japonica*. Hier kommen sie aber in viel grösserer Zahl pro Feld vor; sie betragen nämlich im Frühholz 2 bis 6, meist 4 oder 5, bei Grenzzellen selten 7, und im Spätholz 1 oder 2, meist 2 pro Feld. Abgesehen von dem Fehlen der Tüpfel an den Markstrahl-tangentialwänden, ist dieses Holz mehr dem *Juniperus*-Holz ähnlich als dem von *Cryptomeria japonica*. Von dem letzteren kann es dadurch unterschieden werden, dass die Markstrahl-tüpfel viel reichlicher vorhanden sind und dass die Strahlhorizontalwände stärkere „lochporige“ Verdickung zeigen.

#### CHAMAECYPARIS OBTUSA S. et Z. (Hinoki).

Das kirschrötlich bis gelbrötlichweiss oder rötlichgelb gefärbte Kernholz geht je nach dem Exemplar etwas schroff oder sehr allmählich in gelblich-weissen Splint über. Die recht schmale Spätzone ist ganz scharf begrenzt.



Die Markstrahlen sind gleichmässig sehr fein und nur schwer sichtbar. Die gefärbten Striche treten auf dem Hirnende stellenweise parallel der Jahringgrenze auf. Das Holz ist meist schmalringig, gerad- und feinfaserig, dauerhaft und riecht eigentümlich.

*Cham. obtusa* S. et Z. forma *formosana*, Hayata. Dieses Holz ist rötlichgelb, äusserst schmalringig, gerad- und feinfaserig und riecht angenehm und dauernd.

ANATOMISCHER BAU. Das Holzparenchym befindet sich meist im Spätholz und besitzt die mehr oder weniger verdickten, oder mit „Höcker“ versehenen Querscheiden. Die Hoftüpfelpori an den Tangentialwänden der Tracheiden sind schmal und meist gekreuzt. Die Verdickung der Breitfasern sowie der Rundfasern ist ca.  $3\mu$ . Beim Holz von Formosa sind sie  $3\mu$  und  $4-5\mu$  respective. Die Markstrahlen sind 2 bis 13, meist 4 bis 9 Zellen hoch (beim Holz von Formosa 2 bis 19, meist 5 bis 13). Obwohl die Horizontalwände des Strahlparenchyms dünner sind als jene von *Cryptomeria japonica* und fast glatt gebaut, so zeigen sie doch hier und da spärliche „lochporige“ Verdickung. Die Tangentialwände desselben sind dünner als die horizontalen und meist fast senkrecht gerichtet. Die Behöfung der „cupressoiden“ Tüpfelung ist ziemlich deutlich; der etwas breite Porus derselben ist meist geneigt. Bei den sehr weithumigen Tracheiden wird er breit-elliptisch und ist fast horizontal gelegt. Bei den englumigen Spätholzzellen ist er dagegen schmal-elliptisch bis linear und aufwärts gerichtet. Diese Tüpfel kommen im Frühholz zu je 1 bis 3, meist je 2, und im Spätholz zu je 1, bei Grenz- zelle je 1 oder 2 pro Feld vor.

#### CHAMLEOCYPARIS PISIFERA S. et Z. (Sawara).

Der Splint ist schmal und gelblichweiss, während das Kernholz schwach kirschrot bis rötlichgelb, zeitweise ganz schwach gelb ist. Die Markstrahlen sind sehr fein, doch deutlich von der Grundmasse unterscheidbar. Man beobachtet öfters auf Hirnende die dem Jahring parallel laufenden gefärbten Striche, auch auf Längsfläche hier und da schwach gefärbte kurze Linien derselben. Es ist sehr leicht, meist schmalringig, geradfaserig, ordentlich sehr gut spaltig und geruchlos.

ANATOMISCHER BAU. Dieses Holz ist im grossen und ganzen wie bei der vorigen Art gebaut. Die deutlichen „Höcker“ einer Harzparenchymquerscheide betragen 2 bis 5 je nach der Lumenweite. Die nestartigen, harzführenden Flecke sind nichts anderes als die regellos zerstreute Gruppe der Tracheiden von verschiedener Gestalt und Grösse, welche an allen Seiten mit Hoftüpfeln versehen sind. In diesem Teil sind die Tracheiden unregelmässig angeordnet und etwas dickwandig (Fig. 30 u. 31). Es ist hier zu bemerken, dass dieses Holz histologisch von der vorigen Art nur durch die Dünnwandigkeit und den stärkeren Unterschied in der Verdickungsweise zwischen Früh- und Spätholz unterschieden werden kann, obwohl dies keineswegs das durchgreifende Merkmal ist. Die Zellwandungsdicke des Früh- und Spätholzes beträgt 2 resp. 3-4 $\mu$ .

#### JUNIPERUS CHINENSIS L. (Byakushin).

Das Splintholz ist ziemlich breit und gelblichweiss. Das Kernholz ist rot bis rötlichviolett und riecht andauernd angenehm. Die Jahrringe sind mehr oder weniger stark wellenförmig. Die Markstrahlen sind ausserordentlich fein und mit unbewaffnetem Auge kaum erkennbar. Die stark gefärbten Streifen treten hie und da ganz unregelmässig auf. Das Holz ist schmalringig.

ANATOMISCHER BAU. Das Holz besteht aus Tracheiden und Harzparenchym. Letzteres ist im Früh- und im Spätholz zerstreut und bildet auch eine regellose Gruppe in der Mittelzone, die makroskopisch als eine gefärbte Linie erkennbar ist. Die Querscheide desselben ist höckerreich, und man kann gelegentlich dort auf Querschnitt die korrespondierenden Tüpfel beobachten (Fig. 33). Die Hoftüpfel an den Radialwänden der Tracheiden sind im Frühholz kreisrund bis etwa elliptisch, im Spätholz viel kleiner und mit schräg-elliptischen, nicht selten gekreuzten Pori versehen. Die Wandung der Tracheiden ist im Frühholz 2-3 $\mu$  und im Spätholz 3-4 $\mu$  dick. Die Markstrahlen sind 2 bis 27, meist 6 bis 17 Zellen hoch und sehr harzreich. Die Strahltangentialwände sind auch höckerreich und zeigen im Tangentialschnitt leiter- bis netzförmige Verdickung, was man „Juniperus-Tüpfelung“ nennt, da sie ein charakteristisches Merkmal des *Juniperus*-Holzes bildet (Fig. 33 u. 34). Die Horizon-

talwände sind auch tüpfelreich und im allgemeinen mit einer Vertiefung versehen, wo sie sich mit Tangentialwänden treffen. Die „cupressoiden“ Tüpfel mit etwas schmalen Pori kommen bei der Grenzzelle zu je 1 bis 4, meist je 2 (Frühholz), und je 1 bis 3, meist je 2 (Spätholz), und bei der Innenzelle zu je 1 oder 2, meist je 1, pro Feld vor.

JUNIPERUS RIGIDA S. et Z. (Nezumisashi).

Das Splintholz ist schmal, gelblichweiss und vom Kernholz scharf begrenzt. Das letztere ist dunkel- bis rötlichgelb. Die haardicke Spätzone tritt durch die besonders dunkle Färbung ausgeprägt hervor und läuft feinwellig. Das Holz ist reich an Markflecken, die meist gelbbraun gefärbt sind. Die Markstrahlen sind sehr fein, aber doch deutlicher als bei der vorigen Art und daher erkennbar.

ANATOMISCHER BAU. Histologisch zeigt dieses Holz denselben Bau wie *Juniperus chinensis*, obwohl makroskopisch beide gut unterschieden werden können. Die Tracheidenwandung beträgt im Frühholz  $2-3\mu$  und im Spätholz  $3-4\mu$ . Die Markstrahl tüpfel mit breiten Pori treten im Frühholz zu je 1 bis 6, meist je 3 (Grenzzelle), und zu je 1 bis 4, meist 1 oder 2 (Innenzelle), pro Feld auf. Im Spätholz werden die Pori schmal und kommen zu je 1 oder 2 (Grenzzelle) und je 1 (Innenzelle) pro Feld vor. Dieses Holz neigt zur Bildung der gelbbraunen parenchymatischen Markflecke, die von gefächerten Tracheiden begleitet sind.

ABIES FIRMA S. et Z. (Momi).

Das Splint- und Kernholz sind von derselben Farbe; es ist meist weiss, zeitweise schwach rötlichgelb. Das schwach violettrotlich bis violettbraun gefärbte Holz ähmt dem *Tsuga*-Holz; das gedrückte Holz ist auch dem letzteren sehr ähnlich. In solchen Fällen kann der unten zu erwähnende mikroskopische Befund als entscheidendes Unterscheidungsmerkmal der beiden Hölzer benutzt werden. Bei *Abies*-Holz ist der Übergang von Frühzone in Spätzone meist scharf, aber nicht selten etwas allmählich. Die Markstrahlen sind reichlich an Zahl wie bei *Picea*, aber unterscheiden sich dadurch, dass



sie bei *Abies* auf Hirnende ganz gleichmässig fein und schwer erkennbar sind. Auf Spiegelfläche sind sie sehr deutlich und geben dieser Fläche ihren eigentümlichen Glanz. Das Holz ist meist breitringig. Das normale Holz ist leicht. Es hat einen eigentümlichen an „Shibu“<sup>1</sup> erinnernden Geruch, der beim Anhauchen stärker wird. Überdies führt es, wie Tsugen, unständige Harzgänge, die bezüglich ihrer Entstehung und Verteilung von den ständigen Harzgängen grundverschieden sind. Diese unständigen Harzgänge bilden zusammen manchmal in der Tangentialrichtung eine kreisbogenförmige Reihe. In der Regel kommen sie wie bei anderen *Abies*-Arten in einer schmalen violettschwarzbraunen Streifung eingeschaltet vor.

ANATOMISCHER BAU. Dieses Holz besteht nur aus Tracheiden, die im Frühholz  $2-3\mu$  und im Spätholz  $3-6\mu$  dickwandig und auch an den Tangentialwänden des letzteren mit Hoftüpfeln versehen sind. Das Holz hat häufig eine Tendenz zu Markfleckenbildung, beides in Spät- und Frühzone, aber vorherrschend in der ersteren, wo die sog. traumatischen Harzgänge sich befinden. Diese abnormalen Harzgänge, deren Auftreten nur auf die Axialrichtung beschränkt ist sind stets in grosser Anzahl in einer dem Jahrring parallelen, peripherischen Zone reihenweise angeordnet und mit stark verdicktem Epithel bekleidet (Fig. 39, 41, 43, 44, 45 u. 46). Die Markstrahlen sind stellenweise zweireihig, aber in der Regel einreihig und sehr variabel in der Höhe, also 1 bis 63, meist 8 bis 28 Zellen hoch. Ebenso wie die horizontalen sind auch die tangentialen Wände der Strahlparenchymzellen sehr stark lochporig verdickt, und man kann reichlich auf Quer- und Tangentialschnitt die einander entsprechende sog. „Abietineen-Tüpfelung“ beobachten. Jede von diesen mit verdickten Strahlparenchymzellen versehenen Markstrahlentüpfel der Abietineen d. h. *Abies*, *Picea*, *Tsuga*, *Pseudotsuga* und *Larix*, wird je aus zwei mit einander korrespondierenden der Tracheiden und Parenchymzellen zusammengesetzt, während dieselben bei Taxodiaceen, Cupressineen u. a. einfach den anstossenden Tracheiden angehören. Diese letztere Art der Tüpfelung lässt sich am bequemsten irgend auf einem Quer- oder Tangentialschnitt leicht erblicken. Man vergleiche Fig. 47 u. 56 mit Fig. 29. Aus

1. „Shibu“ ist eine aus den Früchten von *Diospyros Kaki* hergestellte, in der Praxis vielfach gebrauchte Flüssigkeit, deren Hauptbestandteil Gerbstoff ist.



dem Gesagten folgt natürlich, dass die Markstrahltüpfel je nach der Form der beiden Tüpfel mannigfaltig gebildet werden können. Falls nun die beiden von gleicher Form und Grösse sind, so entsteht ein „lochporiger“ Tüpfel. Ausserdem geschieht es nicht selten, dass auf einem optischen Durchschnitt nur einer der beiden Tüpfel sich nachweisen lässt. Im allgemeinen sind die den Tracheiden angehörenden Tüpfel breit- bis schmal- elliptisch, während die der Parenchymzellen mehr oder weniger rundlich sind; sie treten im Frühholz zu je 1 bis 4, meist je 2, und im Spätholz zu je 1 pro Feld auf. Das Holz ist vornehmlich durch das Vorhandensein der Strahlparenchymzellen ausgezeichnet, worin oft die Krystalle von Calciumoxalat in so kolossaler Menge zu beobachten sind, dass die niemals übersehen werden können (Fig. 40). Diese Krystalle sind meist von der Form einer rhombischen Tafel und einer Kombination derselben mit dem Klinopinakoid, oder eines anderen Zwillingskrystalls. Zum Nachweise derselben kann man bekanntlich Schwefelsäure anwenden, wo man die Wirkung der letzteren durch Erwärmen ganz bedeutend beschleunigen kann. Nach meiner Untersuchung von zahlreichen, von verschiedenen Gegenden sowie von verschiedenen Stammteilen herrührenden Proben konnte ich mich überzeugen, dass die Strahlparenchymzellen, oder wenigstens die Grenzzellen derselben, in der Regel mehr oder weniger mit Calciumoxalat versehen sind. Nur beim Druckholztheile scheint dieser Krystall äusserst selten vertreten zu sein oder gänzlich zu fehlen. Die anderen *Abies*- und *Picea*-Arten führen auch diese Krystalle, doch sind sie viel geringer an Menge und viel sporadischer in ihrem Auftreten als bei *Abies firma*.

Die Hölzer der unten anzugebenden *Abies*-Arten sind dem histologischen Baue nach mit dem von *Abies firma* sehr nahe verwandt.

#### ABIES SACHALINENSIS Mast. (Todomatsu).

Das Holz ist grauweisser glänzend im Vergleich zu *Abies firma* und sehr schwach violetttrüblich gefärbt. Es ist schmal- oder mittelschmahringig, geradfaserig und führt öfters Harzgallen.

ANATOMISCHER BAU. Die Rund- und Breitfasern sind 2-3 resp. 3-4 $\mu$  dick. Die Markstrahlen sind 1 bis 30, meist 7 bis 21zellig. Die Markstrahltüpfel

treten auf wie bei *Abies firma*. Bei diesem Holz konnte ich das reichliche Auftreten der die Harzgänge begleitenden und gefächerten Tracheiden nachweisen (Fig. 42 u. 43).

ABIES VEITCHII Lindl. (Shirabe).

Das Holz ist grauweiss und besitzt *Picea*-ähnlichen Glanz. Der Übergang zwischen Spät- und Frühzone ist schroff. Es ist leicht, schmalringig und geradfaserig.

ANATOMISCHER BAU. Die Rund- und Breitfasern sind 2-3 resp. 3-5 $\mu$  dick. Die Markstrahlen sind 1 bis 34, meist 7 bis 18 Zellen hoch. Die Markstrahltüpfel kommen im Frühholz zu je 1 bis 5, meist je 2, und im Spätholz zu je 1 pro Feld vor. Ich bemerkte das Strangparenchym am Ende des Jahrrings d. h. als sog. Endzelle, und zwar in der Nähe der abnormalen Parenchymanhäufung (Fig. 44).

ABIES HOMOLEPIS S. et Z. (Nikkōmomi).

Das Holz ist meist weiss, oft nur schwach gefärbt.

ANATOMISCHER BAU. Die Tracheiden sind im Frühholz 2 $\mu$  und im Spätholz 3-5 $\mu$  dickwandig. Die Markstrahlen sind 1 bis 21, meist 6 bis 15zellig. Die Zahl der Markstrahltüpfel pro Feld ist wie bei *Abies firma*.

ABIES UMBILICATA Mayr et Tabeuf. (Hesomomi).

Das Holz ist weiss, meist mittelschmalringig.

ANATOMISCHER BAU. Die Rundfaser ist 3 $\mu$  und die Breitfaser 4-7 $\mu$  dickwandig. Die Markstrahlen sind 1 bis 23, meist 5 bis 14 Zellen hoch. Die Markstrahltüpfel verhalten sich wie bei der vorigen Art (Fig. 48).

ABIES MARIESII Mast. (Aomoritodomatsu).

Das Holz ist weiss, meist schmalringig.

ANATOMISCHER BAU. Die Rundfaser ist 2 $\mu$  und die Breitfaser 3-4 $\mu$

dickwandig. Die Markstrahlen sind 1 bis 24, meist 5 bis 15 Zellen hoch. Die Markstrahlktüpfel treten im Frühholz zu je 1 bis 3, meist je 2, und im Spätholz zu je 1 pro Feld auf.

TSUGA SIEBOLDII Carr. (Tsuga).

Das Holz ist kirsehrötlichgrau bis schwachrötlichweiss. Nur nach der Austrocknung werden Splint- und Kernholz etwas verschiedenfarbig. Die Frühzone ist von der Spätzone scharf begrenzt. Das schwach gefärbte Holz ist zeitweise von dem von *Abies firma* kaum unterscheidbar. Die Markstrahlen sind gleichmässig fein und bräunlichgelb bis gelblich gefärbt, während die der *Picea*- und *Abies*-Arten immer gelblich sind; daher unterscheiden sie sich meistens in der Färbung von der Grundmasse. Die Jahrringe zeigen oft die in der Verwendung hoch geschätzte eigentümliche Feinwelligkeit, sog. „Kashime“ (Fig. 54). Ferner ist das Holz, insbesondere das breitringige, mit breiter Spätzone versehene, oft weiss gefleckt, was die Bearbeitung dieses Holzes ziemlich erschwert. Diese Flecke rühren von den mit Harzsubstanz erfüllten Zellen her. Was die traumatischen Harzgänge betrifft, so verhalten die sich ganz wie bei *Abies*-Arten. Das Holz ist mittelhart und nicht leicht.

ANATOMISCHER BAU. Das Holz besteht nur aus Tracheiden und führt unständige Harzkanäle, die als abnormale Bildung erscheinen, wie es bei *Abies*-Arten der Fall ist. Selten findet sich aber das Strangparenchym als Jahrringendzelle (Fig. 50 u. 52). Die Tracheiden sind im Frühholz  $2\mu$  und im Spätholz  $3-6\mu$  dickwandig. An der Tangentialwand des Spätholzes sind zahlreiche Hoftüpfel vorhanden. Die Markstrahlen sind einreihig, nur selten zweireihig und 1 bis 21, meist 4 bis 15zellig. Die Quertracheiden ohne Zacken treten in der Regel mindestens als Grenzzellen auf, wodurch dieses Holz sicher von den *Abies*-Arten unterschieden werden kann (Fig. 53). Die Horizontal- und Tangentialwände der Strahlparenchymzellen sind stark „lochporig“ verdickt. Die Markstrahlktüpfel sind teils nicht „lochporig“ und teils ganz „lochporig“, und betragen im Frühholz 2 bis 4 und im Spätholz 1 pro Feld.

## TSUGA DIVERSIFOLIA Maxim. (Kometsuga).

Verhält sich in allen Beziehungen wie *Tsuga Sieboldii*.

ANATOMISCHER BAU. Das Holz ist anatomisch wie bei der vorigen Art gebaut. Die Wandungsdicke der Rund- und Breitfasern sind 2-3, beziehungsweise 4-7 $\mu$ . Die Markstrahlen sind 1 bis 24, meist 4 bis 16zellig. Das Auftreten des Strangparenchymes als Endzelle sowie der Markstrahltüpfel wie bei der vorigen Art.

## PICEA HONDOENSIS Mayr. (Tōhi).

Das Splintholz ist ziemlich breit, weiss bis gelblichweiss und geht ganz allmählich ins Kernholz über, welches meist hellkirschrötlich ist. Die recht schmale Spätzone ist von der Frühzone ziemlich scharf begrenzt. Die meisten Markstrahlen sind sehr fein, aber deutlich. Sie sind in grosser Anzahl vorhanden, und wohl am zahlreichsten pro Flächeneinheit unter unsern Nadelhölzern. Auch bemerkt man hie und da etwas grössere, wie es bei den andern Horizontalharzgänge führenden Gattungen (*Larix*, *Pseudotsuga*, *Pinus*) stets der Fall ist. Das Auftreten der Vertikalharzgänge beschränkt sich fast nur auf die Spätzone, oder mindestens auf die Nähe derselben; sie sind nur in geringer Menge vorhanden. Dieses Holz ist leicht, schmalringig, fein- und geradfaserig, ordentlich leicht und glatt spaltbar und seidenglänzend.

ANATOMISCHER BAU. Das Holz besteht nur aus Tracheiden und führt ständige Harzgänge. Die Tracheiden sind im Frühholz 2-3 $\mu$  und im Spätholz 3-5 $\mu$  dick und hofgetüpfelt auch an den Tangentialwänden des Spätholzes. Die Vertikalharzgänge sind mit stark verdickten Epithelen bekleidet, schliessen oft zahlreich Thyllen ein, und sind meistens von gefächerten Tracheiden begleitet (Fig. 57 u. 58). Die Markstrahlen bestehen aus Parenchym und dünnwandigen Quertracheiden und sind ein- oder mehrreihig. In letzterem Falle schliessen sie die horizontalen Harzgänge ein, die auch nicht selten mit Thyllen erfüllt sind. Die einreihigen Markstrahlen kommen in kolossaler Menge vor und sind 2 bis 35, meist 10 bis 25 Zellen hoch. Wie die horizontalen Wände der Strahlparenchymzellen, sind auch die tangentialen



sehr reich an der „Abietineen-Tüpfelung“. Die sog. Markstrahltüpfel sind „cupressoid“ bis „podocarpoid“, öfters ganz „lochporig“, besonders bei den dünnwandigen Parenchymzellen. Sie betragen im Frühholz 1 bis 5, meist 2 bis 4, und im Spätholz 1 oder 0 pro Feld. Bei meinen Exemplaren fehlt die Spiralverdickung im Spätholz ganz. Die folgenden *Picea*-Arten zeigen in allen Beziehungen denselben Bau wie *Picea hondoensis*.

PICEA BICOLOR Mayr. (Iramomi).

Das Holz ist im Vergleich mit *Picea hondoensis* etwas schwächer gefärbt.

ANATOMISCHER BAU. Die Rundfaser  $2\mu$  und die Breitfaser  $3-6\mu$  dickwandig. Die einreihigen Markstrahlen sind 1 bis 19, meist 6 bis 10 Zellen hoch. Die Markstrahltüpfel kommen zu je 1 bis 6, meist 2 pro Feld vor.

PICEA AJANENSIS Fisch. (Ezomatsu).

Das Holz ist viel gelblicher; es ist schwächer glänzend als *Picea hondoensis* und führt reichlich Harzgallen.

ANATOMISCHER BAU. Die Wandungsdicke der Rund- und Breitfaser ist 2-3, resp.  $3-7\mu$ . Die einreihigen Markstrahlen sind 2 bis 20, meist 5 bis 13 Zellen hoch. Die meisten Markstrahltüpfel sind mit schmalen Pori versehen und treten zu je 1 bis 4, meist 2 pro Feld auf.

PICEA POLITA Carr. (Baramomi).

Im Vergleich mit den Hölzern von andern *Picea*-Arten verhält sich das Holz dieser Art ganz verschieden in vielen Beziehungen. Zum Beispiel ist die Spätzone ziemlich breit, und ihr Übergang in die Frühzone ist mässig allmählich; ferner fehlt diesem Holz der spezifische Seidenglanz. Es ist weder leicht noch feinfaserig.

ANATOMISCHER BAU. Die Rundfaser ist  $2-3\mu$  und die Breitfaser  $3-7\mu$  dickwandig. Die einreihigen Markstrahlen sind 1 bis 32, meist 7 bis 22 Zellen hoch.

## PSEUDOTSUGA JAPONICA Shirasawa. (Togasawara).

Das Splintholz ist gelblichweiss, und das Kernholz graurosarötlich. Die beiden sind von einander scharf begrenzt. Der Übergang zwischen Spät- und Frühzone in einem Jahrring ist schroff. Die Harzgänge kommen meist in Spätzone zerstreut vor und scheinen hier spärlicher vertreten zu sein als bei *Picea* und *Larix*. Auf Längsfläche sind sie leicht erkennbar. Dieses Holz ist äusserlich von dem von *Larix leptolepis* nicht unterscheidbar, obwohl es meist schwächer in Färbung und weniger harzig als das letztere ist. Die sichere Unterscheidung dieser zwei Holzarten kann nur unter dem Mikroskop ausgeführt werden.

ANATOMISCHER BAU. Das Holz ist im grossen und ganzen wie das von *Picea* gebaut, doch ist es davon unfehlbar zu erkennen durch die Tatsache, dass die spiralige Wandverdickung hier durch den ganzen Jahrring geht. Ausserdem führen bei unserem *Pseudotsuga*-Holz die zackenlosen Quertracheiden Spiralverdickung. Das Strangparenchym, welches ich nur im Zweige bemerken konnte, kommt, wenn auch selten, als die Jahrringendzellen abwechselnd mit den Breitfasern vor. Die Tracheiden sind im Frühholz etwa  $2\mu$  und im Spätholz  $3-6\mu$  dickwandig. Sie besitzen auch an den Tangentialwänden des Spätholzes zahlreiche Hoftüpfel mit schmal-elliptischen, meist gekreuzten Pori. Die Markstrahlen sind denen von *Picea* ähnlich; die einreihigen sind 1 bis 25, meist 3 bis 16 Zellen hoch. Die Markstrahlentüpfel, die stellenweise ganz „lochporig“ sein können wie bei *Picea*, treten im Frühholz zu je 2 bis 5 und im Spätholz meist zu je 1 oder 0 pro Feld auf.

## LARIX LEPTOLEPIS Gord. (Karamatsu).

Das Splintholz ist schmal, gelblichweiss und von dem rotbraunen Kernholz ziemlich scharf begrenzt, wobei die rosarotbraune Frühzone in die stark gefärbte Spätzone schroff übergeht. Von den Markstrahlen sind nur die stärkeren deutlich. Die Harzgänge sind durchaus feiner und spärlicher an Zahl als bei den *Pinus*-Arten, und treten fast ausschliesslich in der Spätzone zerstreut auf. Auf dem Längsschnitt sind sie nur dann sichtbar, wenn das Holz nass ist. Es ist schwer, aber leicht spaltbar.

ANATOMISCHER BAU. Nach dem histologischen Baue hat dieses Holz eine grosse Ähnlichkeit mit dem von *Pseudotsuga*. Als ein Charakteristikum ist zu nennen die Tatsache, dass die Spiralverdickung der Tracheiden nur auf dem Spätholz sich nachweisen lässt, doch bei dem Vorhandensein der spiraligen Streifung fehlt; ferner zeigt die Quertracheide niemals Spiralbildung. Das Auftreten des Strangparenchymes und die Tangentialwandhoftüpfelung des Spätholzes sind ganz ähnlich wie bei *Pseudotsuga*. Die Wandverdickung der Tracheiden ist im Frühholz  $2-3\mu$  und im Spätholz  $3-5\mu$ . Die einreihigen Markstrahlen sind 3 bis 31, meist 7 bis 19 Zellen hoch. Die Markstrahl-tüpfel betragen im Frühholz 2 bis 7 und im Spätholz 1 oder 2 pro Feld.

LARIX DAHURICA Turcz var. JAPONICA Maxim. (Shikotanmatsu).

Das Holz ist dunkelgelblichweiss. Die Harzgänge sind nur auf Hirnende etwas deutlich zu sehen und treten ausschliesslich nur in Spätzone auf, wo sie manchmal einigermassen in der Tangentialrichtung aufeinanderfolgend angeordnet sind. Auf Längsfläche sind sie undeutlich, teils wegen ihrer Ähnlichkeit in der Farbe mit der Grundmasse, teils wegen ihrer Feinheit. Das Holz ist sehr harzig und mit Harzgallen sowie toten Astspuren reichlich behaftet.

ANATOMISCHER BAU. Man kann keinen durchgreifenden Unterschied zwischen diesem Holz und dem der vorigen Art auffinden, obwohl makroskopisch keine Verwechslung zwischen beiden möglich ist. Die Wandungsdicke der Rund- und Breitfaser ist 2-3, beziehungsweise  $3-9\mu$ . Die einreihigen Markstrahlen sind 1 bis 30, meist 10 bis 20 Zellen hoch. Die Markstrahl-tüpfel, die öfters ganz oder fast „lochporig“ gebildet sind, treten im Frühholz zu je 2 bis 6 und im Spätholz zu je 1 bis 2 oder gar nicht pro Feld auf.

PINUS DENSIFLORA S. et Z. (Akamatsu).

Der Splint ist gelbweiss, ziemlich breit und vom Kernholz scharf begrenzt, wo das letztere schwach rötlichbraun gefärbt ist. Beim rötlich-gelben Kernholz ist der Übergang nach dem Splint ganz allmählich. Der schroffe Übergang von der Frühzone in die härtere Spätzone ist hier häufiger



als bei *Pinus Thunbergii*. Die Markstrahlen sind ziemlich leicht erkennbar. Die Harzgänge sind meist in der Spätzone, oder mindestens in der Mittelzone reichlich entwickelt. Das Holz ist schwer und elastisch.

ANATOMISCHER BAU. Dieses Holz besteht nur aus Tracheiden und ist durch den ständigen Besitz der in lotrechter, sowie auch in horizontaler Richtung verlaufenden und mit einem zarten Epithel bekleideten Harzgänge ausgezeichnet (Fig. 69 u. 70). Die vertikalen Harzgänge sind von gefächerten Tracheiden begleitet, wenn auch spärlicher als bei *Picea* (Fig. 72). Die Tracheiden sind im Frühholz  $3\mu$  und im Spätholz  $3-8\mu$  dickwandig. Die Markstrahlen mit zackenförmig verdickten Quertracheiden sind ein- resp. mehrreihig, je nachdem darin die Horizontalharzgänge eingeschlossen sind oder nicht. Im letzteren Falle sind sie 1 bis 17, meist 3 bis 10 Zellen hoch. Im Spätholz scheint die zackige Verdickung stärker zu sein, als im Frühholz (Fig. 71). Die Horizontalwände der Strahlparenchymzellen sind meist glatt und dünnwandig, obwohl man am bequemsten auf Querschnitt hie und da „Eiporen“ erblicken kann (Fig. 69). Die Tangentialwände derselben, die stellenweise nur wenig verdickt sein können, sind stets tüpfellos. Die Markstrahltpfeln sind ganz „gross-eiporig“, wenigstens im Frühholz, und kommen zu je 1, selten 2 oder 3 pro Kreuzungsfeld vor (Fig. 71). Unter unsern Nadelbäumen kann dieses Holz histologisch möglicher Weise nur mit dem von *Pinus Thunbergii* verwechselt werden.

#### PINUS THUNBERGII Parl. (Kuromatsu).

Der Splint ist ziemlich breit und gelblichweiss. Das Kernholz ist auch gelblichweiss oder rötlichgelb. Die Begrenzung zwischen beiden ist durchaus deutlich. Die Markstrahlen sind etwas deutlich. Der Übergang von Spätzone in Frühzone geschieht meist allmählich, besonders bei dem breitringigen Teile. Die Harzgänge sind gröber und zahlreicher als bei *Picea*-, *Larix*- und *Pseudotsuga*-Arten; sie kommen innerhalb eines Jahrrings ganz zerstreut vor und sind zeitweise viel zahlreicher entwickelt, entweder in Spät- oder in Frühzone. Auf der Längsfläche lassen sie sich als ziemlich lange grünbraune Linien erkennen. Das Holz ist meist breitringiger und mehr verharzt, als bei der vorigen Art, ausserdem zeigt es öfters schwarzblaue Streifung.



ANATOMISCHER BAU. Histologisch lässt sich dieses Holz vom vorigen nicht unterscheiden; nur scheint die zackige Verdickung im Frühholz etwas schwächer zu sein als in demselben Teile von *Pinus densiflora*. Die Wandungsdicke der Rund- und Breitfasern ist 3-4, beziehungsweise 4-7 $\mu$ . Die einreihigen Markstrahlen sind 1 bis 19, meist 4 bis 12 Zellen hoch. Die „gross-eiporigen“ Markstrahltüpfel verhalten sich wie bei *Pinus densiflora*.

PINUS PARVIFLORA S. et Z. (Himekomatsu).

Der Splint ist schmal und gelblichweiss, während das Kernholz gelblichrot bis rötlichgelb ist. Die Markstrahlen sind meistens fein, aber deutlich. Die Harzgänge kommen auf Hirnende gelblich gefärbt und zerstreut vor, aber noch etwas zahlreicher in Spät- als in Frühzone. Auf Längsfläche lassen sie sich als verhältnismässig kurze, gelblich bis grüngelb gefärbte Linien bemerken. Es geschieht nicht selten, dass dieses Holz dunkelgrün gefleckt ist; diese Flecke sind aber nichts anderes als durch das Sekret der angrenzenden Zellen des eingeschlossenen Harganges gefärbt Teile. Obwohl dieses Holz manchmal *Picea*-ähnlichen Glanz führt, ist es leicht vom Holz der letzteren durch die folgenden Merkmale unterscheidbar:—die Mehrzähligkeit der Harzgänge, die stärkere Spätzone, und der allmählichere Übergang von der Früh- in die Spätzone, besonders wenn das Holz breitringig ist. Es ist nicht leicht und hat einen eigentümlichen „süssen“ Geruch.

ANATOMISCHER BAU. Dieses Holz besteht nur aus Tracheiden, die im Frühholz 3 $\mu$  und im Spätholz 3-5 $\mu$  dickwandig sind. Die Vertikal- und Horizontalharzgänge haben meist recht dünnwandige, aber auch stellenweise etwas dickwandige Epithelzellen. Das Auftreten der gefächerten Tracheiden ist wie bei *Pinus densiflora*. Die Markstrahlen bestehen aus Parenchym und Quertracheiden ohne Zacken. Die einreihigen Markstrahlen sind 1 bis 16, meist 3 bis 10 Zellen hoch. Die Horizontalwände der Parenchymzellen sind „eiporig“ verdickt. Die Tangentialwände derselben sind teilweise mit „Höcker“ versehen, sodass man solche Tüpfel auf Tangentialschnitt erkennen kann, welche viel ähnlicher der „Juniperus-“ als der „Abietineen-Tüpfelung“, also leiter- bis netzförmig gebildet sind. Die Markstrahltüpfel sind grosseiporig und treten zu je 1 bis 4, meist je 1 pro Feld auf.

Was den histologischen Bau der folgenden 3 *Pinus*-Arten betrifft, so ist er sehr verwandt mit den soeben beschriebenen.

*PINUS KORAIENSIS* S. et Z. (Chōsenmatsu).

Das Holz ist rötlichgelb und riecht stark nach Harz. Es ist meist breitringig und sehr stark verharzt.

ANATOMISCHER BAU. Die Wandungsdicke der Rund- und Breitfasern ist 2-3, resp. 3-5 $\mu$ . Die einreihigen Markstrahlen sind 2 bis 22, meist 4 bis 13 Zellen hoch. Die Tangential- und Horizontalwände der Strahlparenchymzellen scheinen ziemlich stark verdickt zu sein. Die ganz „eiporigen“ Tüpfel betragen 1 oder 2 pro Feld.

*PINUS PENTAPHYLLA* Mayr. (Goyōmatsu).

Das Holz ist meist gelbweiss. Die Markstrahlen sind meistens sehr fein, aber selten stark. Die Harzgänge kommen in meinem Exemplar gewöhnlich ebenso reichlich in Frühzone als in Spätzone vor; selten reichlicher in der ersteren, was bei *Pinus parviflora* nicht der Fall ist. Auf Längsfläche lassen sie sich als längere grüngelbe oder bräunlichgelbe Linien bemerken. Abgesehen von einigen Ausnahmen ist dieses Holz ebenso gebaut wie das von *Pinus parviflora*, und kein entscheidendes Merkmal sowohl makroskopisch als auch mikroskopisch ist vorhanden.

ANATOMISCHER BAU. Die Rund- und Breitfasern sind 2-3, resp. 3-7 $\mu$  dickwandig. Die einreihigen Markstrahlen sind 1 bis 19, meist 4 bis 11 Zellen hoch. Die Markstrahl-tüpfel kommen zu je 1 oder 2 pro Feld vor.

*PINUS PUMILA* Pall. (Haimatsu).

Der Splint ist grauweiss und verhältnismässig breit. Das Kernholz ist rosarötlichgelb und vom Splint etwas scharf begrenzt. Die Markstrahlen sind meistens ausserordentlich fein und zahlreich, so dass sie mit freiem Auge fast kaum sichtbar sind. Doch treten mitunter breitere auf. Die Harzgänge sind zahlreich wie bei *Pinus parviflora*, besonders im Splintteile. Dieselben treten auf Hirnende als braune Pünktchen hervor, und auf

Längsfläche des Splintholzes als gelblichbraune kurze Linien, während sie beim Kernholz fast von derselben Farbe sind wie die Grundmasse.

ANATOMISCHER BAU. Das Holz ist ziemlich gleichmässig gebaut. Die Rundfaser ist  $3\mu$  und die Breitfaser  $3-4\mu$  dickwandig. Die einreihigen Markstrahlen sind 1 bis 8, meist 1 bis 5 Zellen hoch. Bemerkenswert ist es, dass die meisten Markstrahlen wenigzellig und ausschliesslich aus Parenchym bestehen. Sowohl die Harzgänge wie auch die Markstrahlen enthalten den Harzkörper in reichlicher Menge. Ausserdem lassen sich zeitweise zahlreiche harzführende gefächerte Tracheiden erblicken.

Die vorausbeschriebenen Merkmale, nach denen fast alle Gattungen unserer Nadelbäume von einander unterschieden werden können, stelle ich zum Schlusse in Form einer Tabelle zusammen, um damit eine klare Übersicht zu gewähren. Mögen diese mikroskopischen Befunde, zusammen mit den makroskopischen Merkmalen zum Bestimmen unserer Nadelbaumhölzer behülflich sein!

## Tabelle zum Bestimmen der japanischen Nadelbaumhölzer.

## I. OHNE HARZGÄNGE.

A. Nur aus Tracheiden bestehend.

1. Mit Krystallschläuchen ..... *Ginkgo*.
2. Markstrahltpfkel grosseiporig ..... *Sciadopitys*.
3. Tracheiden mit Spinalverdickung ..... *Torreya*, *Taxus*.

B. Aus Tracheiden und Strangparenchym bestehend.

4. Tracheiden mit Spiralverdickung..... *Cephalotaxus*.
5. „Juniperus-Tüpfelung“ vorhanden .....*Juniperus*.
6. Markstrahltüpfelpori auch bei Spätholz breit.....*Libocedrus*.
7. Markstrahlwände ringsum glatt.....*Podocarpus*.
8. Markstrahl tangentialwände glatt, aber horizontal nicht

ganz glatt ..... { *Thujaopsis*, *Cryptomeria*,  
*Chamaecyparis*, *Cunninghamia*.

(Tangentialwände zuweilen mit „Höcker“ versehen)..... *Thuja*.





mehr bei dem Frühholz als bei Spätholz vorkommt, was aber der allgemeinen Regel ganz entgegengesetzt ist.

5. Nach der Untersuchung der von verschiedenen Gegenden, sowie von verschiedenen Stammportionen entnommenen über 100 Holz Proben konnte ich mich von dem stetigen Vorhandensein der Calciumoxalatkrystalle in den Markstrahlzellen von *Abies firma* überzeugen, und zwar kommen sie in sehr erheblicher Menge vor; dabei scheint es mir, dass diese Krystalle in dem Druckholztheile nur äusserst spärlich vertreten sind, oder ganz und gar fehlen. Es wird öfters gesagt, dass die Kisten aus diesem Holz von Ratten gemieden werden; doch bedarf es noch weiterer Forschung um festzustellen, ob diese Tatsache auf die Krystalle, oder auf den eigentümlichen unangenehmen Geruch des Holzes zurückzuführen sei. Möglicherweise könnte das Sägmehl von diesem Holz als gutes Rohmaterial bei der Calciumoxalatfabrikation dienen.

6. Wir bemerken die Tatsache, dass bei dem glatt gehobelten Holz von *Tsuga Sieboldii* oder *Cryptomeria japonica* das Frühholz viel schneller abgenutzt wird als das Spätholz, während bei dem Holz von *Chamaecyparis obtusa* die Abnutzung überall gleichmässig auftritt. Abgesehen von der Verschiedenheit in Härte zwischen Früh- und Spätholz ist diese Tatsache vorwiegend auf die Verschiedenheit in ihrer Zellwandungsdicke zurückzuführen. Bei *Tsuga Sieboldii* und *Cryptomeria japonica* ist dieser Unterschied ziemlich beträchtlich, während er bei *Chamaecyparis obtusa* sehr unbedeutend ist, was die soeben erwähnten Widerstandsdifferenzen von beiden Hölzern verursacht.

7. Da das Holz nach drei Richtungen hin verschieden gebaut ist, ist sein Verhalten den Richtungen nach verschieden. Zum Beispiel ist der Leitungswiderstand des Holzes für Elektrizität stets in der Richtung des Faserverlaufes am geringsten und in der Tangentialrichtung am grössten, was nebst dem radialen Verlauf der Markstrahlen vornehmlich auf der allgemeinen Zellanordnung begründet sein dürfte. In der Axialrichtung, wo die Summe der Querschnittsflächen der Zellwandungen, d. h. die Leitungsfläche am grössten ist, ist es ganz natürlich, dass dieser Widerstand am geringsten ist. Obwohl bei dem Tangentialwiderstand die Leitungsfläche gleich bleibt wie beim Radialwiderstand, sind doch im ersteren Falle die

Stromwege natürlich verlängert und verzweigt, wie man bei irgend einer Querschnittfigur des Holzes bemerken kann, wo die Zellen, besonders des Frühholzes, meist wie bei einem Ziegelgemäuer angeordnet sind. Nach der Rechnung werden wir unter einigen hier nicht zu nennenden Voraussetzungen annehmen dürfen, dass der Widerstand in der Radial- und Tangentialrichtung etwa in Verhältnis von 2 zu 3 stehe. Von derselben Zellanordnung könnte hauptsächlich die stärkere Scherfestigkeit an der Sehnenfläche der Hölzer der Nadelbäume verglichen mit der Spiegelfläche abhängig sein, obwohl hier die geringe Kohäsion zwischen Zellorganen und Markstrahlen in Betracht kommen kann. Näheres darüber werde ich anderswo sagen.

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 Fig. 2. Radialschnitt von demselben.  $\times 65$ .  
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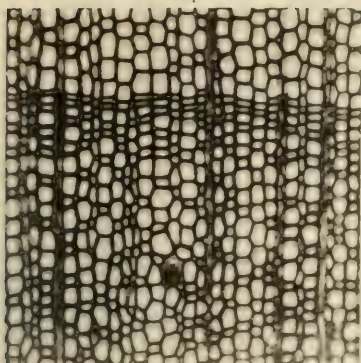
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 ×170.

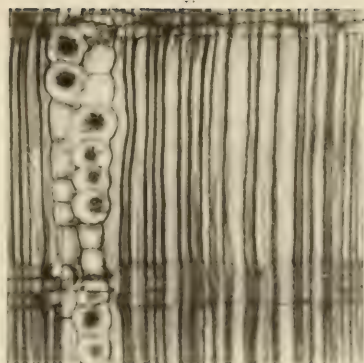
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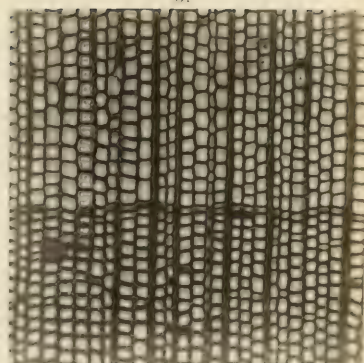




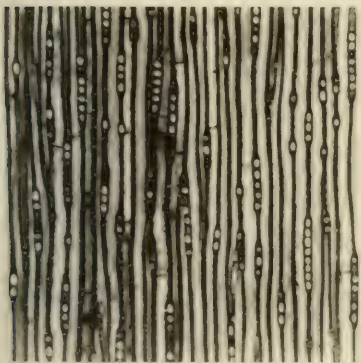
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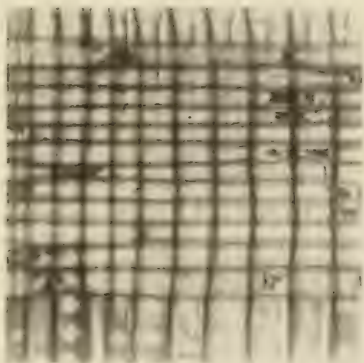
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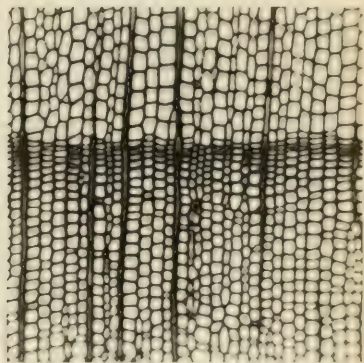
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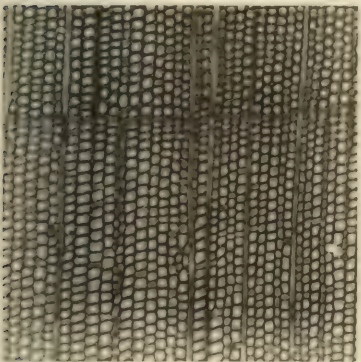
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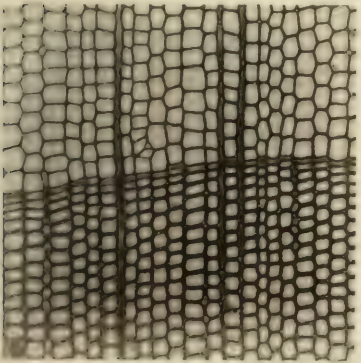
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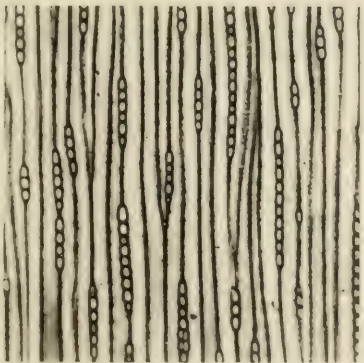
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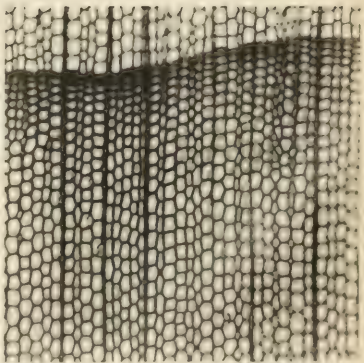
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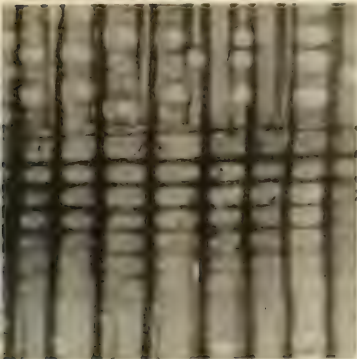


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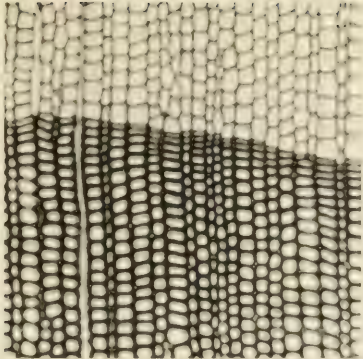




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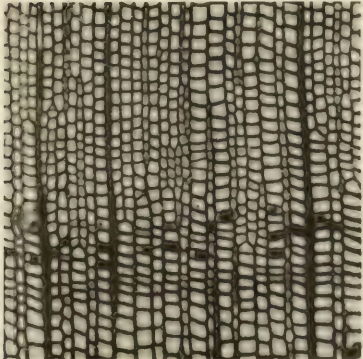
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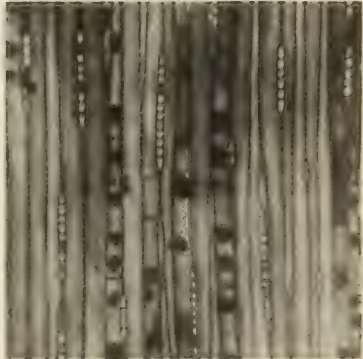
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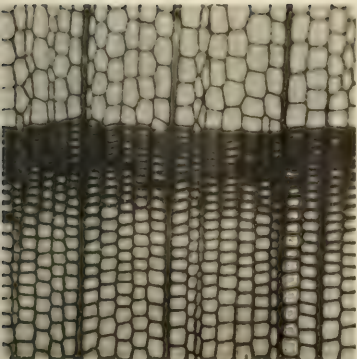
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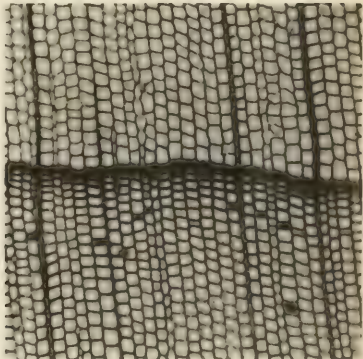
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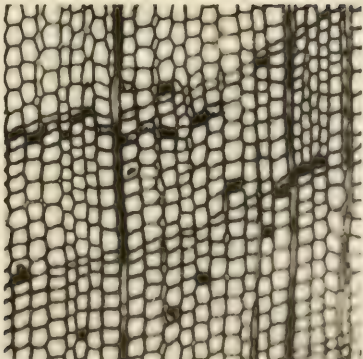
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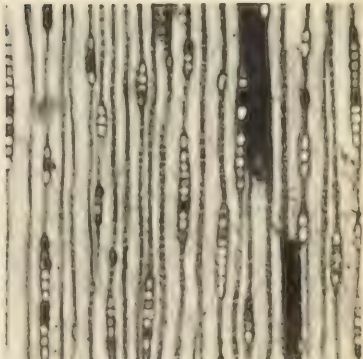
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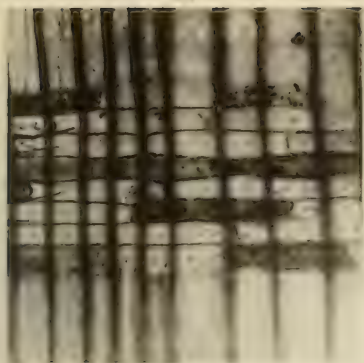
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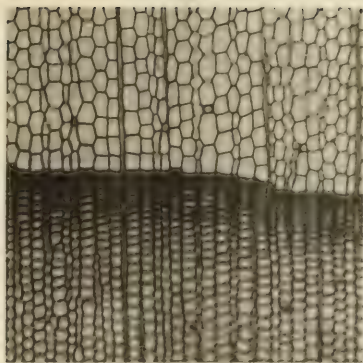




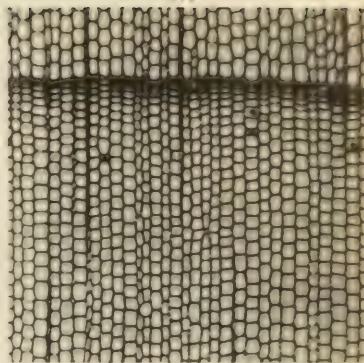
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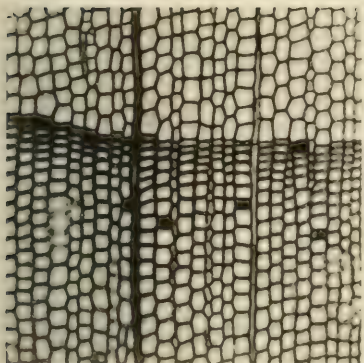
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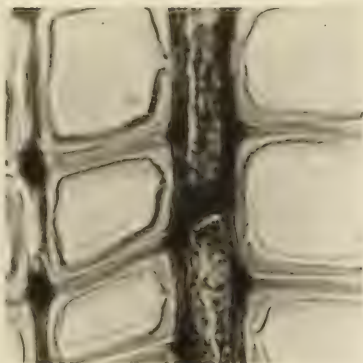
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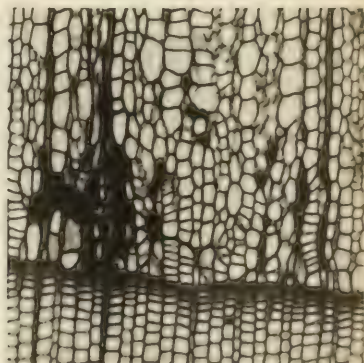
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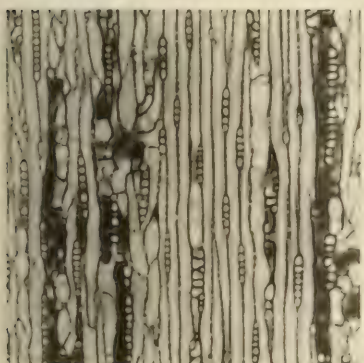
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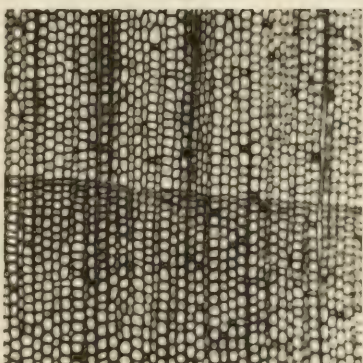
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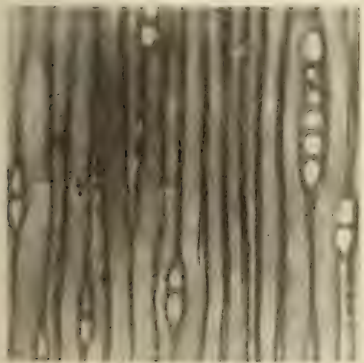
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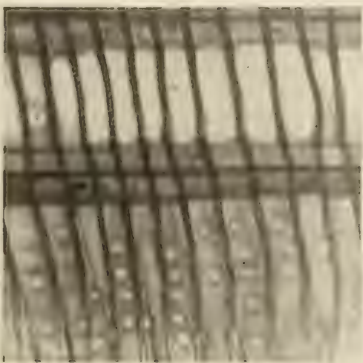
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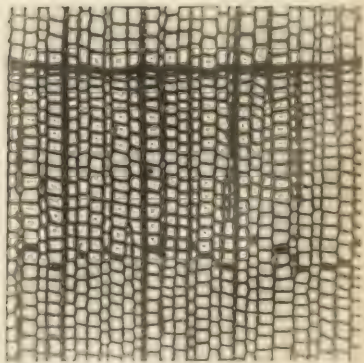
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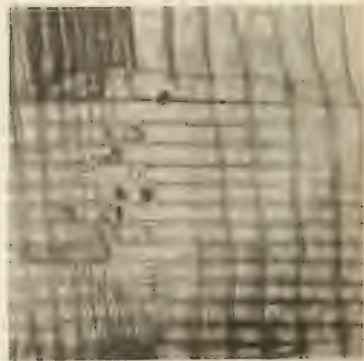
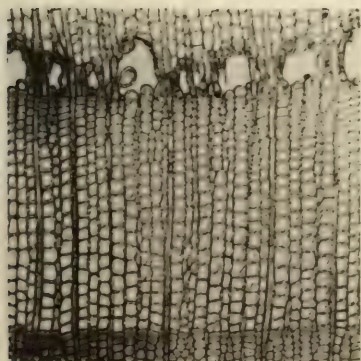
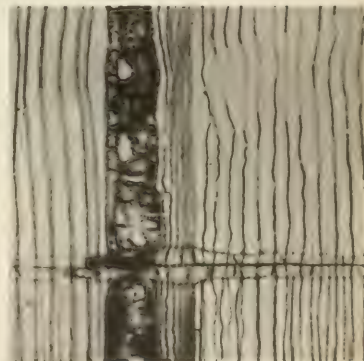
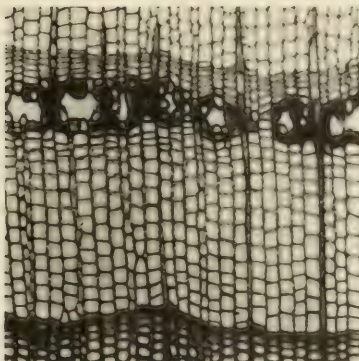
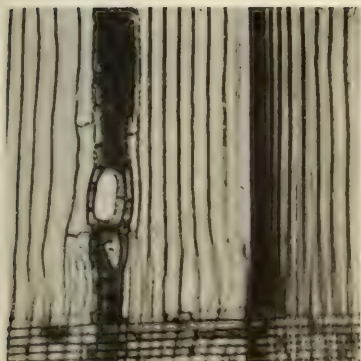
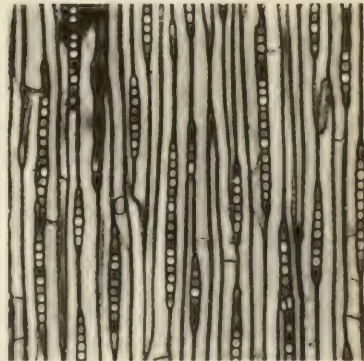
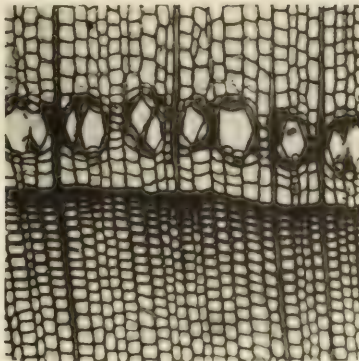
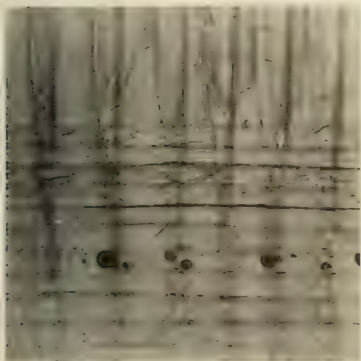
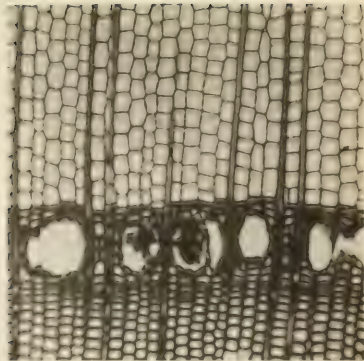
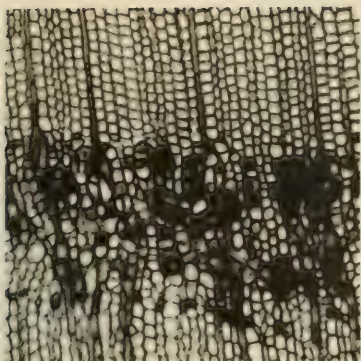


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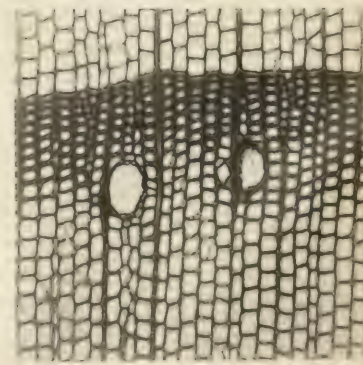
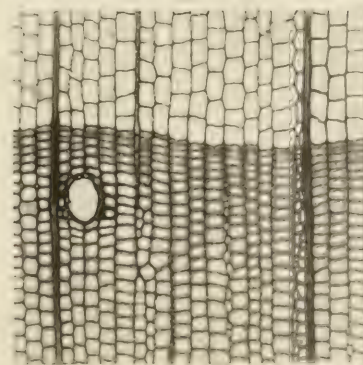
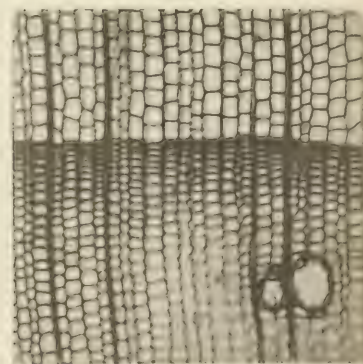
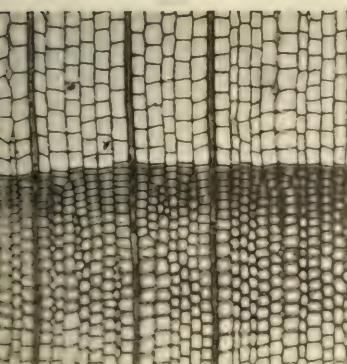
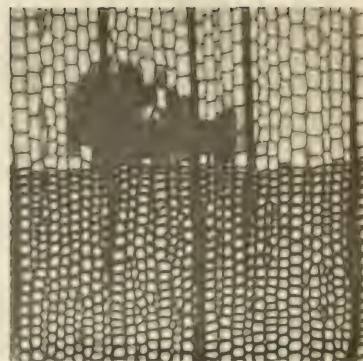
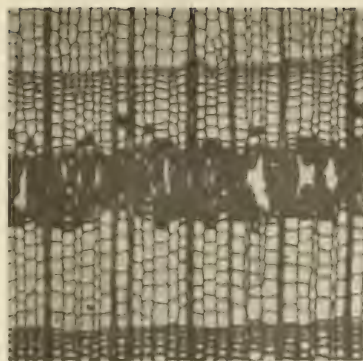
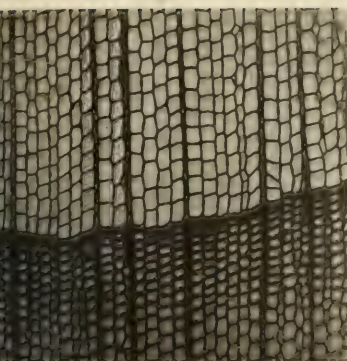






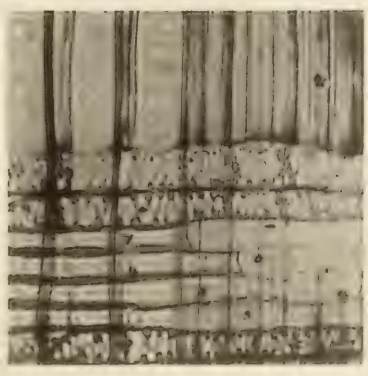
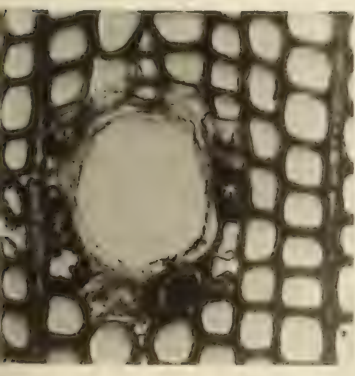
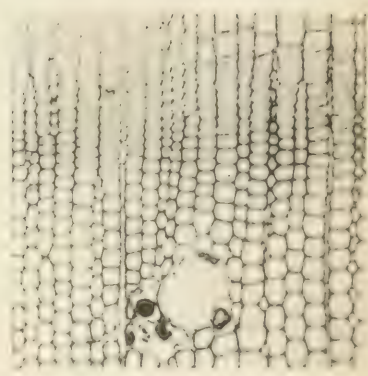
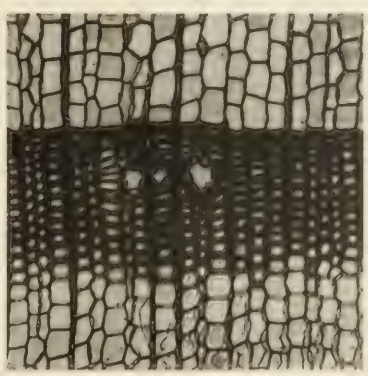
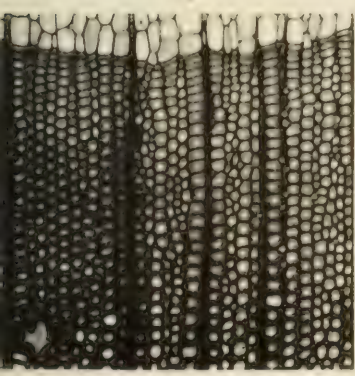
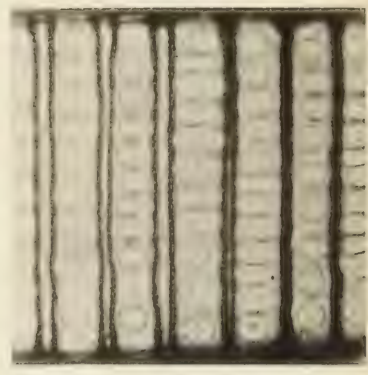
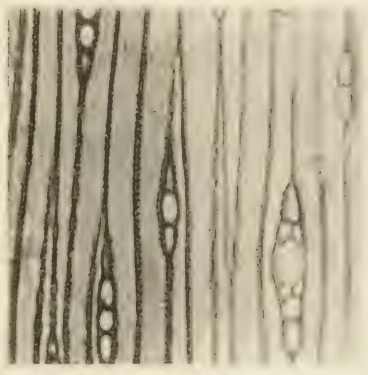
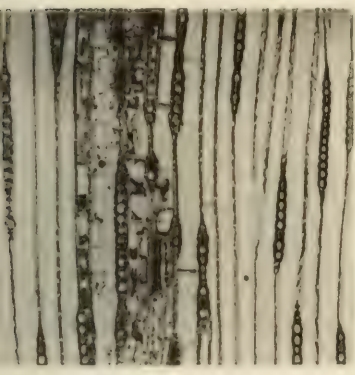
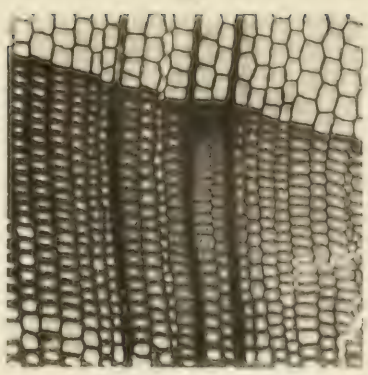
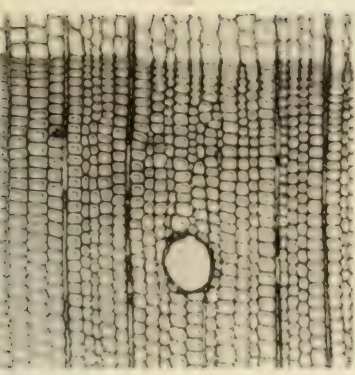






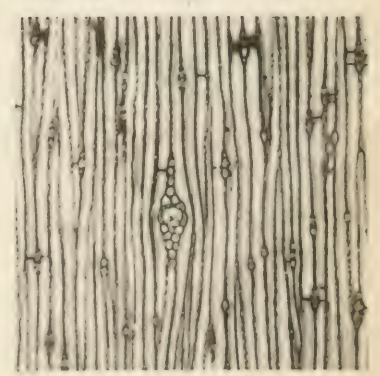
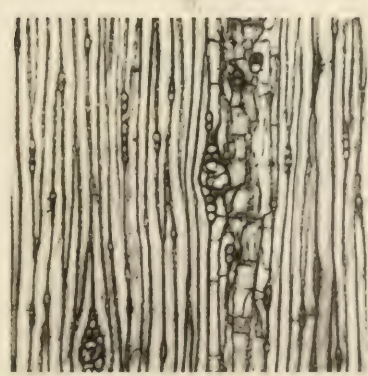
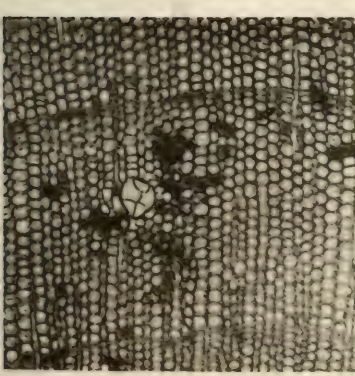
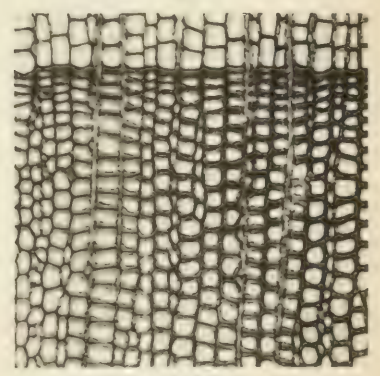
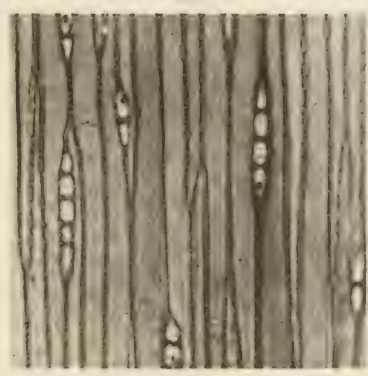
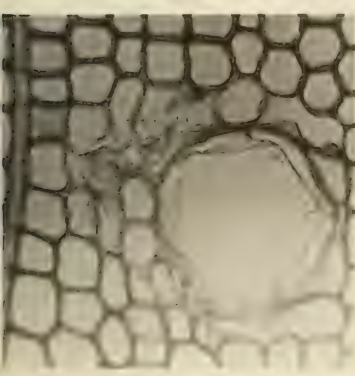
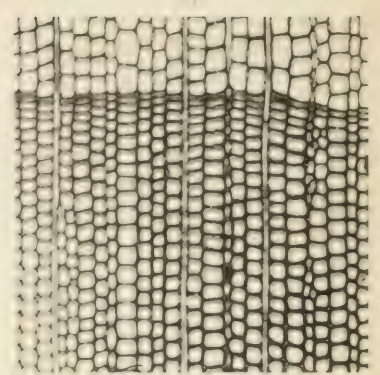
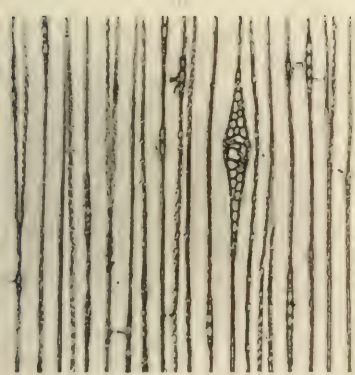
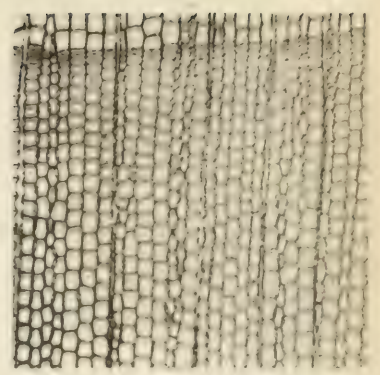
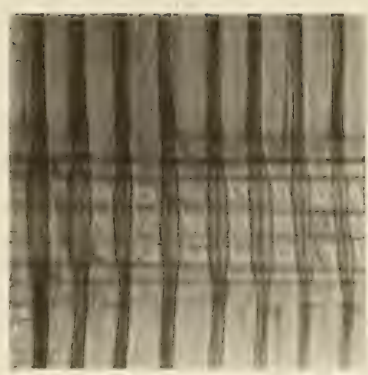
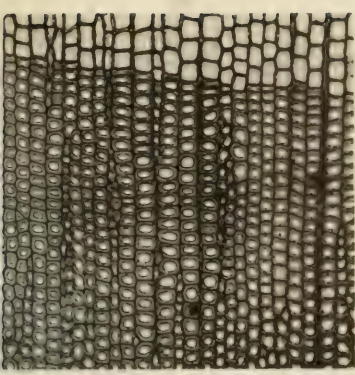
















# On the Development of the Pollen-Grain and Embryo-Sac of *Daphne*, with special Reference to the Sterility of *Daphne odora*.

By

I. Osawa.

With Plates XXV—XXVII and three Text-Figures.

Among cultivated plants there are many which are completely sterile or produce seeds very rarely, though they produce flowers containing well developed stamens and pistils. The causes of the sterility of these plants are probably various.

It is a well known fact that the sterility of plants is often caused by hybridization, and a number of cases of these sterile hybrids has been studied by many investigators during the last few years. Among them we may mention JUEL (1900), CANNON (1903), CORRENS (1902), GREGORY (1905), GATES (1907), and TISCHLER (1903, 1906, 1908). According to these, several irregularities, which cause the degeneration or abnormalities of the pollen-grains or embryo-sacs of these sterile hybrids, occur generally during their development. Thus fertilization does not take place in these plants and sterility is the result.

The sterility of plants may sometimes be due to the influence of long culture or unfavourable climate, as has already been fully discussed and experimented by DARWIN (1868), MUECKE (1908), TISCHLER (1908), WULF (1909), and others.

There are also many so-called self-sterile plants which, though both pollen-grains and embryo-sacs are produced normally, remain sterile

for some unknown reasons, when they are pollinated with their own pollen. It is reported by FRITZ MUELLER (1868) that in *Notylia* the pollen-grains and the stigma act as poison on each other, so that the germination of the pollen-grain is prevented, and both the stigma and the pollen-grain die off together after about two days. JOST (1907) has studied several self-sterile plants, as *Corydalis cava*, *Secale cereale*, *Lilium bulbiferum*, *Hemerocallis fulva*, *Cardamine pratensis*, and some Leguminosæ. According to him, the self-sterile plants produce mostly normal pollen-grains and ovules, and the pollen-grains may easily produce pollen-tubes, which may enter into the tissue of the stigma of the same flower, but in these cases, the tube, as a rule does not reach the ovule for some unknown reason, and sterility results.

It is also probable that the sterility of plants may sometimes be caused by mutation, as has been maintained by some authors (GATES, 1907; GEERTS, 1909; TISCHLER, 1908, 1910).

*Daphne odora* Thunb. is a native of China and is commonly cultivated in Japan. The plant is found in full blossom about the middle of March, and each flower contains eight stamens and a single pistil with one anatropous ovule. The anthers and ovules are well developed and seem to be quite normal externally, but the plant is entirely sterile in our garden. In this case the sterility appears not to have been caused, at least, by hybridization, because there is no description or reason to believe that the plant is produced by cross-breeding. So I thought that it would be interesting to investigate the cause of sterility and to compare it with the normal fertile species of the same genus. For this purpose, *Daphne pseudo-mezereum* A. Gr. and *Daphne kiusiana* Miq. were also studied. Both species grow wild in Japan, but the material for my present study was mostly collected from the plants in the Botanical Garden of the Agricultural College.

There are but few investigations dealing with the development of the pollen and the embryo-sac of *Daphne*. PROHASKA (1883) has studied the development of the endosperm and embryo of certain species of *Daphne*, but he gives no descriptions of the earlier stages of their development. STRASBURGER (1884, 1885, 1909) has also described the formation of the endosperm in certain species of *Daphne*, but he gives only a short statement in regard to the development of the embryo-sac.

This investigation was chiefly carried out in the Botanical Laboratory of the College of Agriculture of the Imperial University of Tokyo under the guidance of Professor K. MIYAKE, to whom I here express my sincere gratitude.

### Material and Methods.

The greater part of the material for the present investigation was collected at the Botanical Garden of the College of Agriculture, small collections have been made also at other places. Collections were chiefly made from the 1st of November 1908 till the middle of April 1909. From the 1st of September till November 1909, an additional collection was made for the study of the earlier stages. In the early stage of development the whole flower-buds with young stamens and pistils were dipped into a killing fluid. As they hold an immense quantity of air, their sinking in the fluid is prevented, but after immersing into 95% alcohol they sink at once. If the flowers were older, ovaries were separated from the buds and dipped into the killing fluid. At this stage the ovarian wall increases in thickness, so it is better to cut off a part of its wall for the rapid penetration of the fluid, but great care must be exercised not to injure the ovules.

Several fixing reagents were employed, but FLEMING's stronger solution and chromo-acetic solution containing 1% chromic acid and 1% acetic acid were most satisfactory. FLEMING's weaker solution, and weak chromo-acetic solution containing 0.7% chromic acid and 0.3% acetic acid worked also well, but alcoholic solution of acetic acid and picro-acetic solution did not bring good results.

The sections were cut from 5 to 20 $\mu$  in thickness. For staining several reagents were used, among these the more satisfactory combinations were found to be safranin-gentian violet-orange and HEIDENHAIN's iron-alum-hematoxylin. For the study of chromosomes the latter was most useful and satisfactory.

## **Daphne odora, Thunb.**

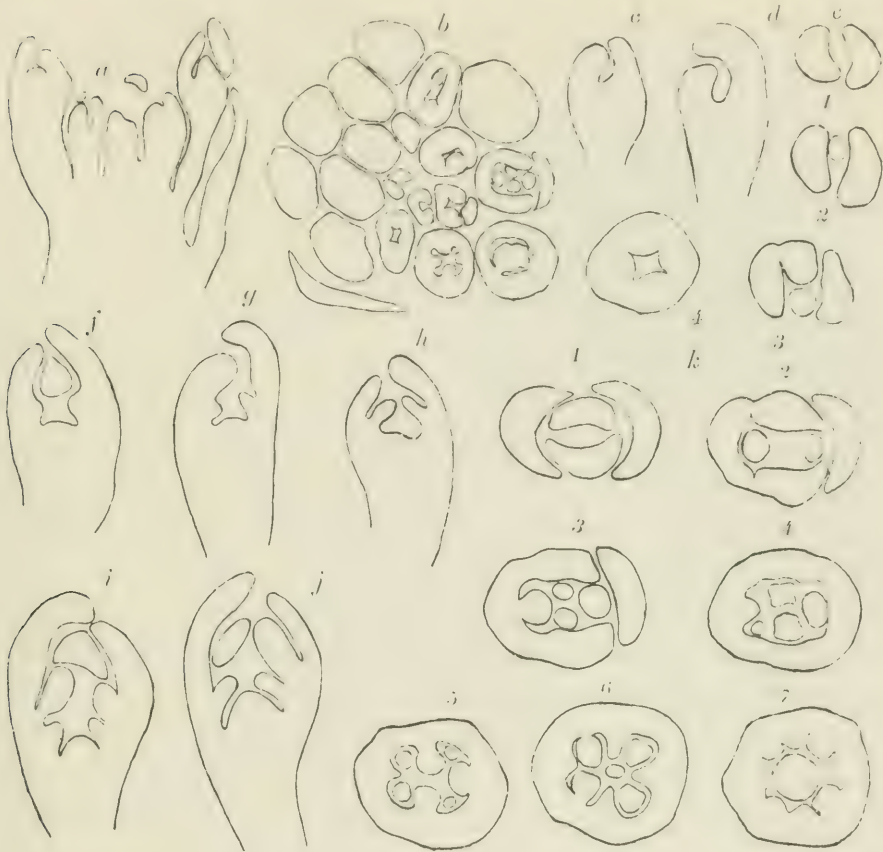
### **1. DEVELOPMENT OF THE FLOWER.**

The flower bud of *Daphne odora* appears at the end of the summer on the top of the growing shoot. In the material gathered in the middle of September we may find it in the condition as is shown in Text-fig. 1, *a*, *b*, which is naturally thickly enclosed by the numerous bracts, though they are not shown in the figures. The number of flowers in a single bud is not constant and in a larger bud there are often twenty or more of them, and as there are great differences in stages of development of the flowers even in a single bud, it is not difficult to trace their development. The flowers appear as protuberances from the growing point or the top of the stem (Text-fig. 1, *a*). These swellings push out rapidly, and meanwhile a cylindrical mass of tissue grows up at the apex of each receptacle (Text-fig. 1, *c*, *d*, *e*). This is the primordium of the perianth and its upper portion divides into four leaves (Text-fig. 1, *e*), in which two leaves are, at first, larger than the other two. Shortly afterwards the primordia of the stamens are produced as protuberances of the inner surface of the floral tube, as is shown in Text-fig. 1, *f*, *g*, *h*, *i*. The upper four appear first and are soon followed by the lower four. During the development of the stamens the pistil appears also as a swelling from the basal part of the inner surface of the floral tube (Text-fig. 1, *h*, *i*, *j*, *k*). All parts of the flower thus produced now grow gradually and differentiate as is to be described in the following chapters.

### **2. MICROSPORANGIUM.**

In the earlier stages, the young meristematic cells of the anther are very small and equal in size. At the next stage studied many cell divisions and differentiations of tissue take place, thus the sporogenous cells, tapetum, and wall tissue are produced. Text-fig. 2 shows a transverse section of a single locule containing the resting pollen-mother-cells. The epidermis consists of a single layer of cells and just beneath it there are several, usually three,

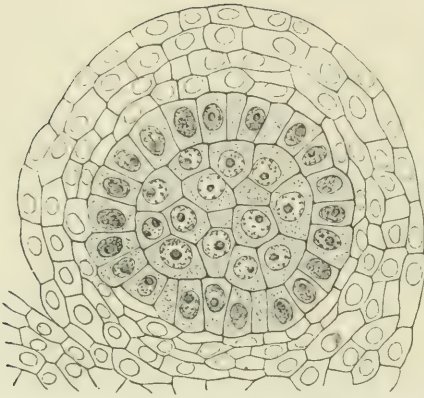




Text-fig. 1. Development of the flower. *a, b*,  $\times 25$ ; *c-k*,  $\times 55$ . *a*, longitudinal section of flower bud. *b*, cross section of the same. *c*, longitudinal section of single bud. *d*, the same in older stage. *e*, serial cross sections of a bud in nearly the same stage with *d*. *f-i*, longitudinal sections of flower buds in more advanced stages; *k*, serial cross sections of a bud in nearly the same stage with *i*.

layers of cells. They are the so-called middle layers, which are rather thin and appear to be pressed by the inner layer cells, the tapetal cells. The latter form a well organized sheath enclosing the sporogenous tissue. The pollen-mother-cells, forming a central mass of tissue, can easily be distinguished from other cells by the larger size of the nuclei, dense cytoplasm, and by their staining character towards reagents.

In the earlier or resting condition of the nuclei of the pollen-mother-cells, the cells usually form a compact tissue and are angular in form as in Text-fig. 2. The nucleus contains one large nucleolus, which is commonly placed near the nuclear membrane. Two nucleoli nearly equal in size may



Text-fig. 2. A portion of transverse section of the anther.  $\times 400$ .

sometimes be found in a single nucleus. Besides these nucleoli, there occur generally a number of deeply staining bodies, which distribute in the periphery of the nucleus and are connected with one another by very fine linin-fibres. These bodies might be considered to be the equivalents of the so-called "prochromosomes" (Fig. 1) (OVERTON, 1905). The number of these bodies, however, cannot be exactly determined in many cases, though they may sometimes be counted as nearly the same as that of the sporophytic chromosomes. Their arrangement also seems to have no regularity, though we may often find that some of them are arranged in pairs end to end or side by side on linin-fibres. The resting stage of the nucleus continues a comparatively long time and with the approach of synapsis the linin-threads become more numerous and increase in thickness, thus forming a more clearly defined net-work (Fig. 2). During these stages the small chromatic substances irregular in size and form increase in number and are distributed on linin-fibres.

The approach of synapsis is indicated by the contraction of the linin-fibres separating from the nuclear membrane. The chromatic bodies which were distributed irregularly in the nuclear cavity now begin to fuse to one another and finally form a few large bodies, which also assemble gradually on one side of the nuclear cavity, being accompanied by the condensation of the linin-fibres. These contractions of the reticulum and the chromatic masses proceed more and more, until they become a deeply staining compact ball as in Fig. 3, and sometimes we find a few delicate fibres extending into the nuclear cavity which give frequently a false appearance of doubling. The synapsis stage lasts for a fairly long time as is shown by the frequency of its occurrence in the material sectioned. Then the spireme shortens and thickens and the synaptic ball gradually loosens its structure with the result that a thickened and very much shortened thread appears

(Fig. 4), which is yet difficult to trace in its denser portion. Such a so-called "dolichonema" stage seems to last for a comparatively short time and to pass very quickly into the next stage. The spireme seems to be a homogeneous single thread in many preparations, though some looped portions of the spireme give sometimes the false appearance of a longitudinal splitting as is shown in Fig. 4. The spireme gradually increases in thickness and decreases in length, and after a short time there appear indications of a process of segmentation of the spireme, thus it is transformed into a chain of chromosomes. The process of segmentation appears not to occur simultaneously throughout the entire length of the spireme. In Figs. 5 and 6 we may see early stages of this process, where the chromosomes are present as long bent rod-like or more or less spindle-shaped bodies, with linin-fibres connecting them end to end. The contraction and condensation which occur in the spireme now continue in these chromosomes until they become nearly globular or pear-shaped bodies. In Figs. 7 and 8 the spireme has just broken into groups of chromosomes, each group showing the chromosomes arranged end to end as in *Oenothera* (GATES, 1907, 1908; GEERTS, 1909). In Fig. 8 the larger portion of the spireme has already split into chromosomes, but a few portions yet exist as spiremes, which present a more or less moniliform appearance. The linin connections between the chromosomes become longer and more delicate, and then disappear gradually. In the diakinesis stage, each two of these chromosomes arrange in pairs, end to end (Figs. 9 and 10), but this is not always the case, and we very often found that many of the chromosomes were so separated and scattered that it was impossible to determine in what relation they stood to one another.

In the late diakinesis stage a felt-work of fibrillae appears in the cytoplasm around the nuclear membrane. By their aggregation in several regions the multipolar spindle is formed (Figs. 11 and 12), and meanwhile the nuclear membrane and nucleolus disappear, thus the spindle fibres enter into the nuclear cavity and attach themselves to the chromosomes. But the multipolar spindle stage does not last long, and quickly rearranges itself to form the typical bipolar spindle (Fig. 14 *a*, *b*). At this time the chromosomes, which are distributed irregularly in the nuclear cavity, are drawn into the equatorial plate of the heterotypic spindle, and gradually



arrange themselves more or less regularly. With the contraction of the spindle fibres each bivalent chromosome which forms in the nuclear plate splits now into daughter chromosomes, which begin to move towards the poles. The daughter chromosomes, however, appear not to travel towards the poles pace to pace in many cases, e. g., some of them had already reached the poles of the spindle, while the others were on the way or still remained on the nuclear plate in pairs. So that in the metaphase of the first mitosis, we find many chromosomes which are scattered irregularly on the spindle fibres as is shown in Figs. 14-16.

The number of chromosomes has been counted in various stages and in most cases it appears to be 14 for gametophyte, but occasionally 12 or 13 were counted. In Fig. 8 we see 28 single chromosomes and in Fig. 17 we may count clearly 12 chromosomes in each daughter nuclei; in Fig. 21 which shows an anaphase of the heterotypic mitosis, one of the daughter nuclei has 12 chromosomes, while the other has 14 of them. The variation in the number of chromosomes is also observed in *Morus alba* (TAHARA, 1910) and *Zea Mays* (KUWADA, 1911). The somatic number of chromosomes was also examined in the nucellar and epidermal cells of the young ovule, and appears to be probably twenty eight for the sporophyte (Fig. 35). So the first nuclear division of the pollen-mother-cell must be reducing and heterotypic.

In the early anaphase of the heterotypic division each chromosome splits longitudinally and often gives an appearance of a short and thickened V or H (Figs. 17, 18, and 19). This splitting is evidently a premature fission of each chromosome in preparation for the second mitosis. The group of 14 split chromosomes is best observed in polar views of late anaphases of the first mitosis, or after the daughter nuclei are produced. At a later stage the split chromosomes sometimes appear as more or less dumb-bell shaped bodies, since the contraction and condensation of the chromosomes continue until this time. After the heterotypic mitosis the daughter nuclei never pass into the true resting stage and the chromosomes never lose their identity completely, though they anastomose with one another and assume amoeboidal shape (Fig. 20).

After a short interval each daughter nucleus prepares for division and



the second spindle is soon formed. The chromosomes move towards the nuclear plate of the spindle, where they seem to arrange themselves more regularly than in the first division (Fig. 22). The two homoeotypic spindles are formed simultaneously, but the position of both spindles is not always the same. In Fig. 24 they are in parallels, but in Fig. 23 they are nearly at right angles to each other. Meanwhile the splitting of the chromosomes which are arranged in the equatorial plate becomes complete, and each daughter chromosome moves towards the poles of the spindle (Figs. 23 and 24). When the daughter chromosomes have reached the pole, nuclear membrane is formed around these chromosomes, and a small nucleolus makes its appearance in each nucleus. At this or a somewhat earlier stage the number of chromosomes can be counted (Fig. 26).

Shortly afterwards cell membranes are simultaneously produced between these four grand-daughter-nuclei, thus forming a typical tetrad, and the nuclei pass into the resting stage by the branching and anastomosing of the chromosomes. The tetrad thus produced grows rapidly and then escapes from the mother-cell-wall, forming the pollen-grains.

### 3. ABNORMALITIES OF THE POLLEN-GRAINS.

In *Daphne odora* several irregularities may take place in the development of the pollen-mother-cells. The resting and synapsis stages of them however, seem to pass through normally, though in a few sections I met with those in which the mother-cells and tapetum lose their turgor, and the contents stain deeply with safranin or haematoxylin, indicating that their degeneration has set in, as is the case with *Syringa* (JUEL, 1900; TISCHLER 1908), *Gossypium* (CANNON, 1903), *Lathyrus* (GREGORY, 1905), and in *Oenothera* (GATES, 1907).

In *Daphne odora*, however, such an early disintegration appears to be rather rare and a great majority of them pass into the tetrad stage. The multipolar spindle sometimes appears as early as the late spireme stage in which the chromosomes are not yet completely separated (Fig. 13). A similar phenomenon was observed by JUEL (1900), TISCHLER (1908), and NAKAO (1911) in sterile hybrid plants.

In the heterotypic division, chromosomes are very often found scattered

irregularly on the spindle fibres, as above mentioned (Figs. 14, 15 and 16), and occasionally some chromosomes spread out from the spindle and are left behind in the cytoplasm without reaching the poles of the spindle. Such chromosomes may produce very small nuclei after a short time (Figs. 27-29). Similar irregularities were also noticed by JUEL (1897) in the pollen formation of *Hemerocallis fulva*; by TISCHLER (1908, 1910) in the pollen development of *Syringa chinensis* (*S. vulgaris*  $\times$  *S. persica*) and of certain *Musa* species; by GATES (1907) in the sterile *Oenothera* hybrid (*O. lata*  $\times$  *O. Lamarekiana*) and by ROSENBERG (1904, 1909) in a certain *Drosera* hybrid.

The homoeotypic division of the pollen-mother-cell is carried on more regularly as already stated, and I could scarcely find any abnormalities in my preparations. But in the tetrad stage there occur very often more than four cells, e. g., five, six, or seven, exceedingly variable in size, as has also been observed by many authors in cultivated or hybridized plants (WILLE, 1886; BEER, 1907; TISCHLER, 1906; GATES, 1907). The nuclei of these supernumerous cells are probably partly produced by amitotic division of some nuclei of the tetrad, with the exception of those extremely small nuclei which are due to the scattered chromosomes. In many cases the nuclei of some daughter cells appear as oblong or hourglass-shaped bodies, showing they are in the way of amitotic division, and this amitotic division of the nucleus is followed by the drawing apart of the cytoplasm (Fig. 32). These phenomena have also been clearly observed in fresh materials which indicate many transitional features of drawing apart of both nucleus and cytoplasm. Such amitotic division sometimes stops before it is completed and the cell reaches the matured stage in that condition, thus we may often observe a few irregular dumb-bell-shaped pollen-grains in the loculus, though their contents are sometimes degenerated (Fig. 33). An amitotic division of the nucleus in the pollen development was occasionally observed and it is mentioned by JUEL (1900), CANNON (1903), SHIBATA and MIYAKE (1908), TISCHLER (1908), KUWADA (1911) and others.

At the tetrad stage each spore contains a large nucleus and is filled densely with cytoplasm, it appears normal though variable in size. But further development is exceedingly irregular. In the stage of bloom we

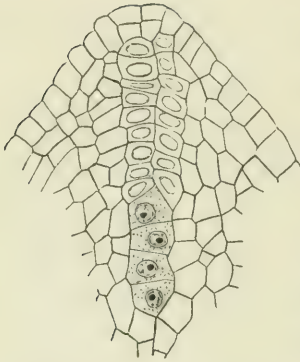
may find many abnormal pollen-grains. Some of these are very small, containing a little dark-stainable substance; these must probably coincide with those pollen-grains produced from the scattered chromosomes in cytoplasm. Some contain a small ill-shaped nucleus and very poor cytoplasm in spite of its normal size and shape. In another pollen-grain, cytoplasm stains deeply, indicating that degeneration has already set in. In others the form of pollen-grain is very irregular and the contents disappear already, and beside these many other irregular grains are to be seen in a loculus (Fig. 33). I not seldom found pollen-grains with two nuclei, a generative and a vegetative. But in many cases it appears that the pollen-grain is destined to degenerate before the nuclear division takes place, by which generative and vegetative nuclei are formed. I have often examined the stigma of the flower of *D. odora*, at the stage of full bloom, and found a great many pollen-grains, which were attached to the stigma. But I never met with pollen-grains, which germinate on it; many of them lose their contents and disintegrate already.

#### 4. MEGASPORANGIUM.

The embryo-sac of *Daphne odora* is derived from a hypodermal cell situated at the apex of the nucellus. The cell grows rapidly and soon becomes discernible as an enlarged oblong cell, which contains a large nucleus and more or less granular cytoplasm. This hypodermal archesporial cell soon divides into two cells by a periclinal wall. The outer or micropylar cell is the so-called tapetal cell. The increase in size of this tapetal cell is followed at once by a periclinal division and this by an anticlinal, and then the daughter cells undergo repeated periclinal divisions. This process may continue until as many as eight or more layers of cells are produced (Text-fig. 3), and the embryo-sac now lies in the very heart of the nucellus. These tapetal cells all persist until the embryo-sac reaches maturity, though they are often found in a more or less compressed condition.

The inner or chalazal cell resulting from the division of the primary hypodermal cell constitutes the primary sporogenous cell or embryo-sac-mother-cell (Fig. 36). Its sporogenous character is plainly shown by the rapid changes which soon take place in both its nucleus and cytoplasm. The





Text-fig. 3. Longitudinal section of young ovule, showing tapetum and megaspores.  $\times 400$ .

embryo-sac-mother-cell grows considerably and it becomes rapidly several times its original size and just previous to the first division of its nucleus the cell becomes unusually long, but is completely filled with cytoplasm. The nucleus contains, as in the pollen-mother-cell, one large nucleolus and a number of prochromosome-like bodies, which are connected by delicate linin-fibres (Fig. 36).

During the resting stage of the embryo-sac-mother-cell, the nucleus increases in size and after a certain period the nucleus begins to show signs of approaching synapsis. The process of synapsis is the same with that of the pollen-mother-cells, which was described in the preceeding chapter. The stage of synapsis seems to be of somewhat long duration (Fig. 37). After a time there occurs gradual loosening of the knot, with a simultaneous migration of the spireme coil to the nuclear cavity (Fig. 38). The nucleolus, here, is seen to remain intact during the whole process and then the spireme ribbon splits into a number of chromosomes (Fig. 39). The process of condensation and contraction of the chromosome-segments proceed more and more until they attain short, bent rod-form, and every two of them make pairs and distribute loosely on the periphery of the nuclear cavity (Fig. 40).

After a short time a heterotypic spindle makes its appearance in cytoplasm. Although I have observed the spindle always in the bipolar condition, I could not determine whether the spindle is multipolar or not at an earlier stage of its appearance, as in the pollen-mother-cell (Fig. 41 a, b). Each pair of chromosomes, which shorten and thicken progressively, until they become dumb-bell or hour-glass shaped, arrange now at the nuclear plate more regularly than in the pollen-mother-cell. When the contraction of the spindle fibres takes place, each bivalent chromosome draws apart into single chromosomes, and the latter begin to move into the opposite poles of the cell (Fig. 42). At the anaphase of the first mitosis the longitudinal splitting of the daughter chromosomes is observed clearly as in the pollen-mother-cell. The number of chromosomes was counted in a few



sections and proved to be nearly 14 for the gametophyte, but sometimes 12 were clearly counted, as in the pollen-mother-cell. Fig. 40 shows the diakinesis stage of a megaspore-mother-cell nucleus, presenting 13 bivalent chromosomes, while in Fig. 41 a, b which represent the metaphase of the heterotypic spindle, we can count only 12 of them.

During the anaphase of the first division a nucleolus and nuclear wall reappear in each daughter nucleus, and a cell membrane is deposited between two daughter nuclei, which divide the original cell into two nearly equal parts, as shown in Fig. 43. The daughter nuclei, however, do not pass into the true resting condition, like that of the pollen-mother-cell. The split chromosomes remain distinct in many cases, though they are somewhat in the anastomosing condition.

The nuclei of these two daughter cells divide again very quickly; two homocotypic spindles are generally formed simultaneously, and the chromosomes are drawn towards the equator, where they arrange themselves in a nuclear plate (Fig. 44). The spindles are directed parallel to the longitudinal axis of the ovule, but this is not always the case, and sometimes the spindle is inclined and in fact almost transverse to the axis. So one may find at the next stage the two daughter cells range side by side instead of one above the other, as in Fig. 46. When the daughter chromosomes reach the poles the nuclear membrane and nucleus reappear in each daughter nucleus and this is followed by the formation of cell walls between the daughter nuclei, thus bringing about a row of four megaspores (Fig. 45). These megaspores are nearly equal in size at an early stage, but soon differentiation occurs between them, when they begin to grow. In many cases observed the innermost of the megaspores develops into the embryo-sac, and a similar condition has been reported by many authors for several plants. The upper three cells now show signs of disintegration, as indicated by the cytoplasm, which becomes more dense and stains more deeply, and the nuclei lose their definite outline at first, and finally the entire cells become much compressed and flattened against the wall cells above (Figs. 47 and 48). Shortly afterwards one may find the disintegrated cells as a dark cap at the summit of the embryo-sac as shown in Figs. 52 and 53. In general, the disintegration of the upper three megaspores takes place simultaneously, but

in some cases it seems to occur one by one, e. g., the next cell above the functional megaspore degenerates first, then the one above, and finally the uppermost one. I have observed in several preparations the figures like Fig. 51, in which the central two megaspores have already degenerated, while the innermost and outermost ones are equally well developed. In another case I met also with some, in which the uppermost megaspore develops well, destined for the future embryo-sac, while the lower three were more or less degenerated (Figs. 49 and 50). Some of these irregularities are also reported in *Apocinum* (FRYE and BLODGETT, 1905), *Oenothera* (GEERTS, 1909; DAVIS, 1910).

The cell destined for the future embryo-sac grows rapidly, soon becoming strongly differentiated from the surrounding cells. Its chalazal end has been prolonged into a somewhat funnel-shaped body and gradually penetrates into the nucellar tissue as in *Tricyrtis* (IKEDA, 1902). In these stages an increase of the cytoplasm in the embryo-sac does not accompany the rapid growth of the embryo-sac, so that large vacuoles make their appearance (Figs. 52 and 53). The nuclei also increase in size and undergo the first division after a certain period. In Fig. 54 the first nuclear division of the embryo-sac is almost completed. During these periods the embryo-sac continues to enlarge, especially in breadth; so that it now becomes ellipsoidal in shape. The two daughter nuclei now move towards the opposite poles, until they reach respectively to the two extremities of the embryo-sac (Fig. 55); here as in other angiosperms, the two nuclei divide again simultaneously (Fig. 56). At this stage, the cytoplasm of the embryo-sac becomes more rare and attaches simply to the periphery of the sac with the exception of the dense mass around these nuclei. The four nuclei produced enter the complete resting condition and situate themselves regularly in the cytoplasm, which makes a thin layer, as in Fig. 57. The embryo-sac and its nuclei grow continuously, and after a certain period the nuclei divide again almost simultaneously, giving rise to a typical eight nucleated embryo-sac (Fig. 58). In *Daphne odora*, however, the disintegration of the embryo-sac takes place at this stage or at a more or less earlier stage. So the typical eight-nucleated embryo-sac is not produced in many cases, and indeed, I found only in a few cases embryo-sacs, which reached the matured stage. In such normal

cases three of the chalazal four nuclei move towards the chalazal region to form antipodal cells, and one of them forms the lower polar nucleus. The four nuclei in the micropylar end assume their characteristic arrangement and give rise to the egg apparatus and upper polar nucleus (Fig. 59). The egg nucleus is found near the base of the somewhat pear-shaped egg cell, and is usually surrounded by several vacuoles. The cytoplasm of the synergids stains more deeply, and each nucleus is much smaller than that of the egg cell. Soon after the polar nuclei move towards each other and remain in contact for a while in the upper portion of the sac (Fig. 59). But after a certain period they fuse completely, though fertilization does not occur (Fig. 60). The antipodal cells which consist of three cells at first, now may sometimes divide; so we may find several antipodal cells more than three in number, e. g., four, five, or six cells, as is shown in Fig. 59. In *Daphne odora*, however, I have never met with embryo-sacs containing so many antipodal cells as other species of *Daphne*, which were described by PROHASKA (1883) and studied by the writer.

##### 5. THE ABNORMALITIES OF THE EMBRYO-SAC.

The disintegration of the embryo-sac of *D. odora* generally agrees with that of *Syringa* and *Ribes* (TISCHLER 1906, 1908). In the stage of the embryo-sac-mother-cell, I have never observed signs of degeneration; heterotypic and homoeotypic divisions were also always normal. The earliest stage, in which I have found the degeneration was as early as the four megaspore stage, as in Fig. 61. But the degeneration at such an early stage seems to be rather rare, since I have seen such a case only in a few preparations. In a later stage, however, their disintegration may occur in various ways. But I will describe here only a few cases, which most commonly take place. In some cases the embryo-sac is exceedingly small, and its contents show signs of degeneration, and form an irregular thin layer attached to the periphery of the sacs, staining deeply with safranin or hæmatoxylin. I have thought at first that these phenomena might be due to the incomplete fixing of the material, but the careful treatment of materials by various methods brought always the same result. In another case the nuclei and the cytoplasm of the embryo-sac is not yet degenerated, but its nuclei were very



variable in size and shape, so that it appears to be probably incapable of further development. When the flower is at the stage of full bloom or still later, the degeneration proceeds more completely. Figs. 62-65 show embryo-sacs at this stage, and some of them contain so far only a few small nuclei. These nuclei also appear too feeble to divide further and are destined to disintegrate after a little while. In a great majority of cases, which have been observed, the embryo-sac was compressed by the surrounding tissue, and the contents of it were almost absorbed by the tissue. In such cases a narrow prolonged space, irregular in shape and size, may be seen (Fig. 64), or it may be displaced completely by the nucellus tissue (Fig. 65). In some cases, though the eight nuclei may occur in the sac, they are small in size and more or less irregular in shape, and moreover, the polarization of the nuclei does not occur in the sac; and they are distributed irregularly in the cavity.

Thus the disintegration of the embryo-sac may proceed in various ways, but it takes place at comparatively later stages of its development and proceeds more slowly than that of *Ribes* and *Syringa*. Such a disintegration of the embryo-sac of sterile plants has been already studied by many authors, and among them we may mention TISCHLER (1903, 1906, 1908), ROSENBERG (1903, 1904, 1909), MUECKE (1908), and others.

### ***Daphne kiusiana*, Miq. and *Daphne pseudo-mezereum*, A. Gr.**

#### **1. MICROSPORANGIUM.**

The pollen development of *D. kiusiana* and *D. pseudo-mezereum* agree with each other, and they also coincide generally with that of *D. odora*. So the following statement may apply equally well to both *D. kiusiana* and *D. pseudo-mezereum*, unless otherwise stated.

Figs. 66 and 81 show the pollen-mother-cells with the nuclei in the resting condition. As in the case of *D. odora*, each nucleus contains, besides the large nucleolus, a number of chromatic bodies variable in shape and size, and here it is frequently possible to count them, finding sometimes more and sometimes less than eighteen. These bodies are connected with one



another by delicate strands. On approaching towards synapsis the chromatic masses increase in number and distribute on the linin fibres, which also now become more numerous and form clearly defined net-works (Fig. 67). In Fig. 82 the nucleus is now in early synapsis stage; the linin-fibres and chromatin substances have begun to contract, separating from the nuclear membrane. This contracting process proceeds more and more, until a compact synaptic knot is produced which lies generally near the nucleolus (Figs. 68, 83 and 84). At this stage the chromatic substances make a few irregularly aggregated masses in the centre of the synaptic knot. After a relatively long duration of synapsis there occurs gradual loosening of the knot, producing a thicker spireme, which is very complexly looped and tangled, so that in the thicker portion it is scarcely possible to trace its structure (Fig. 69). The spireme shortens and thickens gradually and finally there appears indication of a process of segmentation (Fig. 70), which transform the thread into a chain of 18 chromosomes (Figs. 71 and 85).

In *D. pseudo-mezereum*, however, I have not met with these loosely distributed spiremes in dolichonema stage, and the segmented spireme is found so contracted as to suggest conditions of synapsis as in Fig. 85, and this stage is often termed a "second contraction" by some authors.

The eighteen chromosomes, which result from the segmentation of the spireme, are of bent rod-shape or somewhat spindle-shaped, and still connected with one another by the delicate threads which, however, gradually disappear (Figs. 72 and 86). In the diakinesis stage one may find in many cases every two of the chromosomes forming pairs and distribute loosely in the nuclear cavity (Figs. 73 and 87).

As the condensation and contraction which occur in the organization of the spireme continues until these stages, the bivalent chromosomes appear now as dumb-bell shaped bodies, as in the case of *D. odora*. Figs. 74 and 88 show the metaphase of the first or heterotypic mitosis, in which each bivalent chromosome ranges now very regularly on the nuclear plate. In this respect these conditions in *D. kiusiana* and *P. pseudo-mezereum* are in sharp contrast with those of *D. odora*, where the arrangement of the chromosomes on the nuclear plate was very irregular, as has already been described.

The number of chromosomes can be counted very clearly in the polar

view of the nuclear plate (Figs. 75 and 89) at this stage, and it proves to be exactly nine for the gametophyte in both *P. kusiana* and *D. pseudomezerium*, and just the same number is also easily determined in the diakinesis (Figs. 73 and 87) or in the anaphase of the heterotypic division (Figs. 77, 90, and 91). As the number of somatic or sporophytic chromosomes, which was counted in the nucellar cells of the ovule, appears to be eighteen, as in Fig. 97, so the first mitosis must be heterotypic, reducing division.

The two sets of chromosomes (9 in each set) move away normally from one another towards the poles of the spindle, and in anaphase each chromosome undergoes clearly a longitudinal splitting which is a premature fission of the chromosomes in preparation for the second mitosis, as is observed also in *D. odora*. The group of nine split chromosomes is most easily observed in polar views of the late anaphase of the heterotypic division (Figs. 77 and 91).

Organization of the daughter nuclei takes place as usual, and during the interkinesis of the nuclei the chromosomes anastomose with one another and assume a more or less amoeboidal shape, but never lose their individuality throughout these stages (Fig. 92). Fig. 79 shows the metaphase of the second mitosis in which the split chromosomes are carried towards the equatorial plate of the spindle, where they arrange themselves quite regularly. The two spindles may lie side by side (Fig. 93) or at right angle to each other (Fig. 79). After reaching the poles of the spindle each group of the daughter chromosomes is enclosed by a nuclear membrane, and meanwhile a large nucleolus makes its appearance in each nucleus (Fig. 80), and then the nuclei pass gradually to the true resting condition, being followed by the elongation, branching and anastomosis of the chromosomes. Meanwhile the cell membranes are simultaneously produced between these four daughter nuclei, and the normal tetrad is formed, but there occur occasionally more than four spores in a single mother-cell as in *D. odora*. The spores in the tetrad grow gradually and become typical pollen-grains. Fig. 94 shows the uninucleated pollen-grain, and in Fig. 95 the nucleus has already divided into the generative and vegetative nuclei. Fig. 96 shows the pollen-grain attached to the stigma in the flowering period, in

which the generative nucleus has already divided into two vermiform sperm-nuclei.

## 2. MEGASPORANGIUM.

The development of the megaspore-mother-cells of both *D. kiusiana* and *D. pseudo-mezereum* was examined in several stages, but there is scarcely any difference from those of *D. odora*, which have already been described. So we can here omit to describe and sketch their details. The mature embryo-sac is typical in every respect and it is generally oblong in form (Fig. 99), but in *D. kiusiana* it appears to be more obtuse oblong, as in Fig. 100. The embryo-sac contains well formed egg apparatus, polar nuclei and antipodal cells. In the egg apparatus we may observe one large pear-shaped oosphere, containing one large nucleus and granular cytoplasm, which is more or less vacuolated, and two synergids containing smaller nuclei and denser cytoplasm, which stains heavily with FLEMMING'S triple combination. Two polar nuclei remain in contact for some time (Figs. 98 and 99) in a more or less lower or the chalazal region of the sac, but before fertilization they appear generally to fuse completely. Antipodals are always composed of numerous cells (Figs. 98-102), in certain embryo-sacs we may count thirty or more of them. A similar condition was also observed by PROHASKA (1883) in certain species of *Daphne*.

## 3. THE EMBRYO-FORMATION AND THE DEVELOPMENT OF THE ENDOSPERM.

Details of the fertilization process have not been observed in either species of *Daphne*.

Immediately after the fertilization the primary endosperm nucleus may divide in mitosis before the first nuclear division occurs in the oosphere. When these two endosperm nuclei were in the spireme stage, the first division of the nucleus of the oosphere was just observed, as is shown in Fig. 101. Simultaneous divisions of the endosperm nuclei continue rapidly, and when the first division of the oosphere is completed, eight large endosperm nuclei are found in the embryo-sac (Fig. 102). During these stages the embryo-sac enlarges very rapidly and attains an exceedingly elongated form, being accompanied by the rapid growth of the ovule. Meanwhile the



endosperm nuclei continue to divide and scatter now in the cytoplasm, which makes a very thin layer nearly attaching to the periphery of the embryo-sac (Figs. 103-105), as already described by STRASBURGER (1884) in certain species of *Daphne*.

The oosphere remains dormant for a time after fertilization and then divides by mitosis. The first wall formed is transverse, as in Figs. 101 and 102. The next stage of the embryo observed is a typical four celled one (Fig. 103), but further development was not examined in detail; only a few older embryos are shown in Figs. 104 and 105.

### Conclusion.

In *D. odora*, as already stated, not only the development of the pollen-mother-cells is carried on very irregularly and the pollen-grains thus produced are generally sterile, but also the embryo-sacs develop irregularly and many of them are disintegrated during their development. So that the flower almost always remains sterile. In this case, irregularities which occur in the development of the pollen-mother-cells and embryo-sacs are very similar to those of the sterile hybrids which have been studied, by many authors. But it appears to be scarcely possible that this plant is produced by cross-breeding, as already mentioned, and it is more probable, I think, that the sterility is due to long cultivation under different circumstances, as is the case with many other plants studied by several investigators. DARWIN (1868) has already shown us that different circumstances and unnatural treatment may often bring the plant to sterility, and informed us of many interesting facts, concluding that "The view which seems the most probable, and which connects together all the foregoing facts and brings them within our present subject, is, that changed and unnatural conditions of life first give a tendency to sterility; and in consequence of this, the organs of reproduction being no longer able fully to perform their proper functions, a supply of organized matter, not required for the development of the seed, flows either into these organs and renders them foliaceous; or into the fruit, stems, tubers, &c., increasing their size and succulency." In *Daphne odora* the luxuriance of the vegetative portion is also easily observable. He (1859)



also says; "We see that when organic beings are placed under new and unnatural conditions, and when hybrids are produced by the unnatural crossing of two species, the reproductive system, independently of the general state of health, is affected in a very similar manner."

WILLE (1886) has studied the pollen development of certain phanerogames and informs us that the sterility may often occur in cultivated plants as in hybrids, and he adds that "die Störungen in der inneren Organisation, welche durch die veränderten äusseren Verhältnisse, unter welche die Pflanzen durch die Kultur kommen, hervorgerufen werden, können also so durchgreifende sein, dass sie auf Teile einwirken, welche sonst bei der ganzen phylogenetischen Entwicklung sich am meisten unverändert erhalten haben." MUECKE (1909) has studied *Acorus calamus*, which is always sterile in certain parts of Europe, and found that its pollen-grains and embryo-sacs degenerate in an early stage of development. He concluded that the sterility is due to the unfavourable climate of Europe for the plant. Recently TISCHLER (1908) also showed experimentally that the sexual organs of a certain species of *Potentilla* may be affected by unfavourable circumstances, and he also said, that in *Syringa persica* several irregularities and abnormalities take place in the development of the pollen-grains, and here the plant is considered to have become sterile under the influence of cultivation. It is also announced by WAKKER (1896) that nearly a similar phenomenon takes place in cultivated races of sugar-cane; according to him, there occur no anomalies in the wild or half-wild races, but in cultivated races there are found generally several degrees of irregularities, and in extreme cases no reproductive organ is visible. Besides, GUIGNARD (1887), and FAMILER (1896) also stated that in certain cultivated plants several irregularities may occur in the development of the sexual organs.

These irregularities and disintegration of the reproductive organs of the above mentioned plants are also very similar to those of *Daphne odora*, which is described in the preceding chapter. So it may be concluded that the sterility of the plant has been produced by long cultivation.

But, on the other hand, not only the same phenomena as the irregularities and degeneration of the reproductive organs or sterility of plants, but also the variation of the number of the chromosomes are considered to have

been caused by mutation. For instance, *Oenothera lutea*, a well known mutant of *O. Lamarckiana*, is perfectly sterile, and it is reported by GATES (1907), who has studied it cytologically, that the development of the pollen-grains of the former is very irregular, producing only sterile grains. Several fern varieties which were studied by FARMER and Miss DIGBY (1907) show great differences in their number of chromosomes, and these plants may probably be considered to have been produced mutationally. In *Wikstroemia indica*, which is a well known parthenogenetic plant and closely related to *Daphne*, WINKLER (1906) found that not only abnormalities take place in pollen-development, but also disintegration may sometimes occur even in embryo-sacs. Here the plant was also considered to have been produced by mutation. According to DE VRIES (1901) some sterile races of currants, banana, strawberry, apple, and pear are said to be mutants. A *Linaria* mutant found by LOTSY (1906) appears to be sterile, though the normal plants remain always fertile. MEEHAM (1884) found a form of *Halesia tetraptera*, which is considered to be produced mutationally, but of an exceedingly different appearance to its parents, and it shows perfect sterility. TRISCHLER (1908) found that in *Potentilla Tubernaemontani* many irregularities may occur in pollen-development, while in *P. rubens* there occur no irregularities and he believed the former to be a mutant.

Moreover, it is a well known fact that abnormalities and sterility of pollen-grains or the variation of the number of chromosomes almost always occur in parthenogenetic plants, which may also be suggested to be mutants, *Alchemilla* (STRASBURGER, 1904), *Marsilia* (STRASBURGER, 1907), *Hieracium* (ROSENBERG, 1907), &c. In *Daphne*, there exists, indeed, a great difference in the number of chromosomes between normal fertilized and sterile species, that is, in the former—e. g., *Daphne alpina*, *D. mezereum* (STRASBURGER, 1909), *D. pseudo-mezereum*, *D. kiusiana*,—we see generally 9 of them for the gametophyte, while only the latter shows at least 12 of them. Now considering these facts it appears more probable that the sterility of *D. odora* has been caused by mutation rather than by cultivation alone, though it is scarcely possible here to give a definite decision.

### Summary.

1. In *Daphne odora*, the pollen-mother-cell undergoes two mitoses as usual, one heterotypic and one homoeotypic, though irregularities may sometimes take place.

2. In *D. odora*, the largest number of chromosomes was counted to be 14 for the gametophyte and twice that number for the sporophyte.

3. In *D. odora*, several irregularities may take place in the later stage of pollen-development, and the resulting pollen-grains are mostly sterile.

4. In *D. odora*, the embryo-sac-mother-cell also undergoes one heterotypic and one homoeotypic division resulting in a row of four megaspores.

5. In *D. odora*, the innermost or chalazal megaspore generally develops normal embryo-sacs, but disintegration of the latter may occur very often in several stages of its growth.

6. The sterility of *D. odora* is caused by the abnormalities or degeneration of pollen-grains and embryo-sacs, and these irregularities may be considered to be caused by long cultivation or rather by mutation.

7. In *D. pseudo-mezereum* and *D. kiusiana*, the pollen-mother-cell is originated by two successive mitoses, and normal pollen-grains are produced; here the number of chromosomes differs from that of *D. odora*, presenting 9 of them for the gametophyte, and 18 for the sporophyte.

8. In *D. pseudo-mezereum* and *D. kiusiana*, the embryo-sac is formed normally, containing egg apparatus, two polar nuclei and thirty or more antipodal cells.

9. In the fertilized embryo-sac of *D. pseudo-mezereum* the primary endosperm nucleus divides first and then it is followed by the division of the egg nucleus.

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## EXPLANATION OF PLATE 3.

## PLATE XXV.

Figs. 1-45. *Daphne odora*.

- Fig. 1. Pollen-mother-cell.  $\times 1370$ .
- Fig. 2. The nucleus of the pollen-mother-cell in the presynaptic stage.  $\times 1370$ .
- Fig. 3. The same in synapsis.  $\times 1370$ .
- Fig. 4. The same in spireme stage.  $\times 1370$ .
- Fig. 5. The same with more thickened spireme.  $\times 1370$ .
- Fig. 6. The same, showing segmentation of spireme into chromosomes.  $\times 1370$ .
- Fig. 7. The same, showing chain of chromosomes.  $\times 1370$ .
- Fig. 8. The same in more advanced stage.  $\times 1370$ .
- Fig. 9. The same, showing few chromosomes in pairs.  $\times 1370$ .
- Fig. 10. The same in the diakinesis stages.  $\times 1370$ .
- Figs. 11-13. The pollen-mother-cell in the prophase of the heterotypic division, showing multipolar spindle.  $\times 1370$ .
- Fig. 14 a, b. The same in the metaphase of the heterotypic division; here the cell is cut into two serial sections.  $\times 1370$ .
- Figs. 15 and 16. Side view of heterotypic spindle, showing irregular scattered chromosomes.  $\times 1370$ .
- Fig. 17. Anaphase of the heterotypic division, showing premature splitting of chromosomes.  $\times 1370$ .
- Figs. 18 and 19. Telophase of the heterotypic spindle.  $\times 1370$ .
- Fig. 20. A more advanced stage.  $\times 1370$ .
- Fig. 21 a, b. Pollen-mother-cell cut into two serial sections, showing polar view of two nuclear plates in the metaphase of the second division.  $\times 1370$ .
- Fig. 22. Nearly the same stage.  $\times 1370$ .
- Figs. 23 and 24. The late anaphase of the second division.  $\times 1370$ .
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- Fig. 32. Young irregular pollen-grains in tetrad.  $\times 750$ .
- Fig. 33. Irregular pollen-grains.  $\times 610$ .
- Figs. 34 and 35. Polar view of nuclear plate of vegetative cells.  $\times 1370$ .
- Fig. 36. Embryo-sac-mother-cell.  $\times 1370$ .
- Fig. 37. Nucleus of embryo-sac-mother-cell in synaptic stage.  $\times 1370$ .

- Fig. 33. The same in spireme stage.  $\times 1370$ .  
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PLATE XXVI.

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- Fig. 46. Four megaspores.  $\times 900$ .  
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PLATE XXVII.

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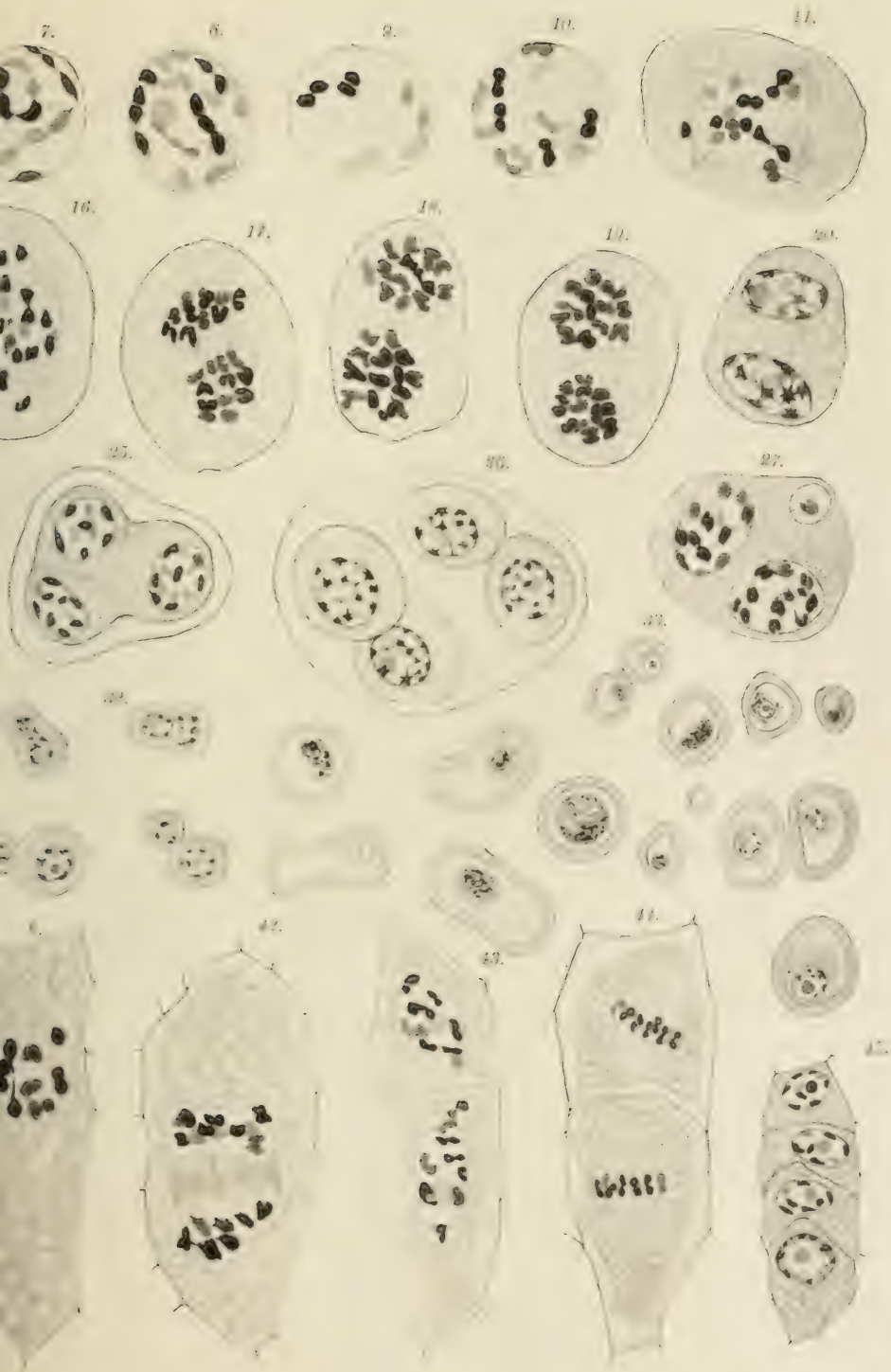










Plate XXVI.







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# Studies on the Mecoptera of Japan.

By

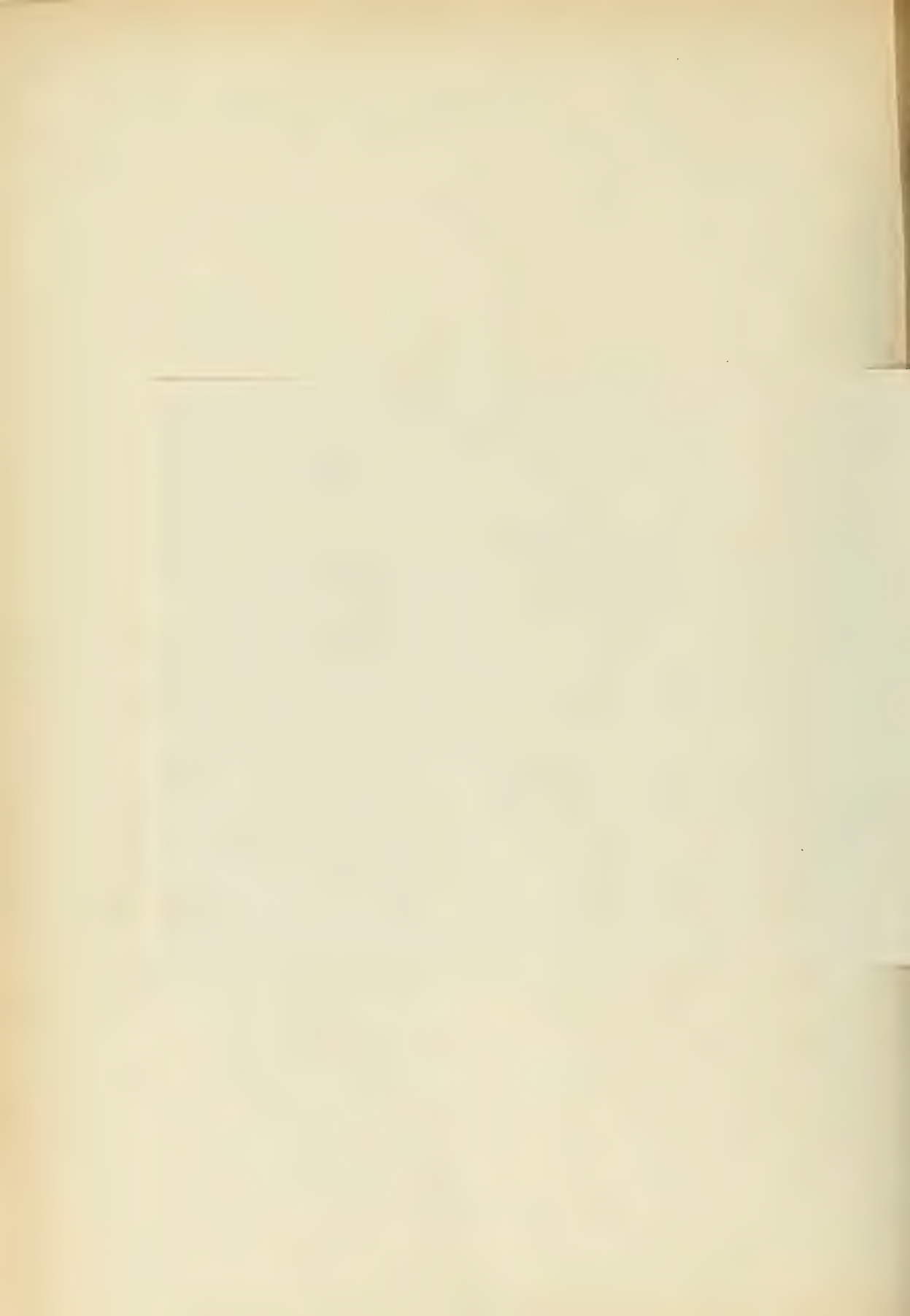
Tsunekata Miyaké.

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## Addenda & Corrigenda.

- P. 269, line 6 from bottom, insert after "ten segments": (or eleven, if the anal internal tube is taken as the eleventh segment).
- P. 270, line 11 from bottom put comma after "the clypeus" and insert: maxillae; for labrum read labium.
- P. 270, line 6 from bottom for labrum read clypeus in both instances.
- P. 270, line 5 from bottom for labium read labrum.
- P. 279, line 3 from top, insert after "ten segments": (or eleven, if the last two joints are counted separately).
- P. 375, line 15 from top, for **Parodoxa** read **Paradoxa**.
- P. 391, line 3 from bottom, insert before "figs. 10": Pl. XXXIV.,

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# Studies on the Mecoptera of Japan.

By

Tsunekata Miyaké.

With Plates XXVIII—XXXVII and six Text-Figures.

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### Introduction.

Of the small order Mecoptera, containing a single family (or two, according to some authors) and a few genera, Japan possesses numerous species. While in Europe or in America not more than twenty species are known, over forty species have already been described as native to Japan. In each case the great majority of the species belong to the genus *Panorpa* and only the remaining few are distributed among other genera. Most of our species of *Panorpa* constitute a peculiar group, as has already been pointed out by M'LACHLAN, therefore they were recently included under the new genus *Aulops*, proposed by ENDERLEIN. Besides, many of our species are noted for their handsome and striking features, so that a study of them may be of some interest to general entomologists.

This work consists of two parts, general and systematic. The first treats of the external and internal structures, habits and life-history; the second contains the descriptions of all genera and species, known to occur in Japan, including 4 new species and 5 new subspecies. However, there is still a number of unexplored spots left in the knowledge of our Mecoptera, which will require the efforts of many entomologists to throw light upon, and for which reason I hope to continue my studies.

I beg to express my warmest thanks to Mr. F. MUIR, Entomologist to the Experiment Station of Honolulu, who kindly assisted me with his valuable advice, during his visit to Japan, notwithstanding that his time was very much occupied. To Profs. SASAKI, ISHIKAWA and GOTO I am deeply indebted for their supervision and suggestions. To Messers HATAKEYAMA, ISSHIKI and NAKAHARA thanks are also due for their courtesy in sending me some interesting specimens.

## Part I. GENERAL.

This part treats of morphology and biology. Of morphology, the venations and wing-markings are studied under special headings, since they have been the principal criteria in taxonomy for many specialists of this order. From the study of venations I have arrived at the conclusion that the peculiarities of venation, pointed out by M'LACHLAN, which characterize most of our species, and which were used by ENDERLEIN to erect a new genus, *Aulops*, have in reality no stability, but present a series of transitional stages from the typical *Panorpa* to the typical *Aulops*, so that the latter genus must be given up. From the study of wing-markings I find that, though they are extremely variable, there exists a certain typical arrangement peculiar to each species, so that if we are acquainted with the range of these variations we can use them for taxonomic purposes. I have further extended the study of wing-markings into an attempt at the settlement of the phylogeny of each species. This of course must be looked upon as only one of the several kinds of evidence that could be brought forward for the determination of kinship.

Under the external structure I have met with facts here and there which appear to be peculiar to Japanese forms, and to be interesting to general morphology. This is the case with the structures of the male genitalia, which in certain species differ considerably from that of the European or American forms. About the eversible vesicle, which is considered as the penis, I am of another opinion. Attention is drawn to the structure of the anal part of the male in *Panorpa* and *Panorpodes*, and to the internal skeleton of the female in *Panorpodes*.

Authorities are not unanimous as to the number of the abdominal segments of the male of *Panorpa*, but it seems to me that nine segments are most commonly recognized. I have, however, from the observation of development, proposed in this report ten segments in the male, by counting the anal tube and the small modified segment, which bears dorsal and ventral appendages, as independent abdominal segments.

The claws, to which much importance is attached by some authors, are treated with comparatively more detail, and it is shown that they are to a certain extent available for taxonomy.



The internal anatomy of *Panorpa* is a very intricate and difficult subject, and the results arrived at by various authors disagree in many points. In this report, however, I only intend to give the general account of the internal organs, and such disputed parts will be almost left untouched. Of course my studies tended to those points, but until now without satisfactory results; the exact investigation of them would take a great deal of time.

The structure of the proventriculus is studied rather in detail, from which we can conclude that the peculiar feature of the proventriculus represented in *Panorpa* occurs similarly in *Panorpodes* and *Bittacus*.

I have already published a paper\* on the habits and life-history of *Panorpa klugi*, so that in this report a brief and general account and supplementary facts only are given. Of *Panorpodes* and *Bittacus* explanations are made rather in detail because the Japanese species of these are described for the first time. Along with those the egg of *Bittacus* is described, which the writer recently succeeded in obtaining.

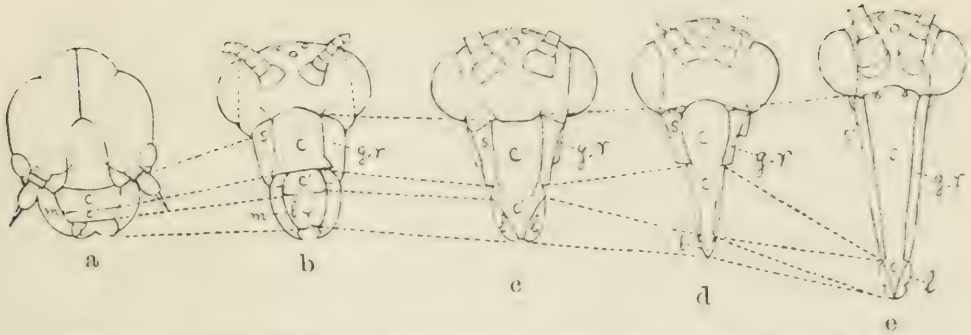
## I. External Structure.

### 1. HEAD.

The head of insects of this order is characterized by the prolongation of its anterior part into a beak. This beak is formed by the elongation of part of the head-capsule and the clypeus and labrum (see Pl. XXVIII., figs. 1-6). It is possible that the lateral portion may also contain a portion of the base of the mandibles. The development of these parts can be plainly seen in text-figure 1, where a shows a view of the head of the larva of *Panorpa*. A suture, in which the two tentorial invaginations are situated, divides the labrum from the head-capsule; the labrum is divided by a transverse suture into the postclypeus (c.) and anteclypeus (c'), the labium is somewhat bilobed. The mandibles are articulated to the head—capsule in the normal position, between the clypeus and maxillæ; the maxillæ and labium are normal. In the head of the pupa of *Panorpa* (b) these parts are all very distinct, the basal portions of clypeus, maxillæ and labium, together with the genal

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Text-figure 1.—Head ( $\times$  about 9): a, *Panorpa* (larva); b, do. (pupa); c, *Panorpodes*; d, *Bittacus*; e, *Panorpa*; c., postclypeus; c', anteclypeus; g. r., genal region; l., labrum; m., mandible; s., suture.

region\* (g.r.) of the head-capsule, have greatly elongated and the mandibles carried forward. In the adult (e) this line of development is carried much further and we have a long beak, with mandible situated near the apex. In the adult of *Panorpodes* (c) we have a stage between the pupa and adult of *Panorpa* which shows the line of development. In *Bittacus* (d) the basal portions are not so greatly developed, but the anteclypeus is much longer in proportion, as are the mandibles.

The epicranium, as in most insects, is convex, and bears very large compound eyes (Pl. XXVIII., figs. 1-6, e.). Between the eyes there are three ocelli situated on the raised ocellar triangle (oc.). Anteriorly from them rise the antennae, which are long, slender and many jointed. They are filiform in *Bittacus* and submoniliform in *Panorpa* and *Panorpodes* (see figs. 19, 20, 21), and inserted in large foramina (figs. 1, 3, 5, af.). The number of joints of antennae are different not only in the three genera, but also in the different species and individuals. In certain species of *Panorpa* there are 43-52 joints and in *Panorpodes* 43-47. In *Bittacus* I could count 16, 18,

\* Though it is almost certain that the region is an elongated portion of the gena, I had formerly some slight doubt about it. As can be seen from Pl. XXVIII., figs. 1-6 and text-figure 1, the portion is separated from the epicranium by a distinct suture s. If one looks on the portion as a joint, it can no longer be considered as a part of the gena; it must be considered as a portion of the mandible. This seems not to be extraordinarily unnatural if one compares text figure 1 a and b, admitting the mandible (m.) of a to correspond to the portion g.r.+m. If this be the fact, the region (g.r.) in question should be considered as a portion belonging to the mandible—the so-called 'basal piece' and would at the same time confirm the statements of WOOD-MASON, CHATIN and SMITH, who consider the mandibles jointed appendages, in spite of the fact that they are generally regarded as a single piece.

19, 20 joints, although the actual number can be one or two more or less than these, since the terminal joints are fused together and very hard to distinguish. The basal joint in *Panorpa* and *Panorpodes* and the basal two joints in *Bittacus* are conspicuously larger than the others. In *Panorpa* and *Panorpodes* each joint bears bristles and hairs; a certain number of conspicuous bristles are situated radially around the anterior end of each joint, which can be seen laterally in pairs in each joint. The terminal joints in *Panorpa* and *Panorpodes* do not greatly differ from the remaining joints, so that the antenna is abruptly ended at the apex. In *Bittacus*, however, the terminal joints become very slender, so that the hairs on them are very conspicuous and the last joint ends in a tuft of hairs from which it can hardly be distinguished (see Pl. XXVIII., fig. 21b).

a. Mouth-parts.

As above stated, the labrum can be seen at the sides of the anteclypeus. In *Panorpa*, the latter is of a triangular form with the apex round (Pl. XXVIII., fig. 10, c'). It is divided by two longitudinal, anteriorly converging ridges into three—one central, two lateral—regions. The latter two regions are the labrum (l.). They are constricted at a spot about one-third from the apex, which gives to the labrum the appearance of another additional portion, so that one might imagine that portion to be the true labrum. The margins and the above stated ridges are fringed with numerous hairs. In *Panorpodes* the anteclypeus is of a high trapezoidal form and the labrum appears as a rather narrow, apical, marginal portion, which has at the middle a small sinuation (Pl. XXVIII., fig. 11, l.). In *Bittacus* the anteclypeus is very narrow and spatulate, and ends rather acutely at the apex. The labrum is very probably the marginal region of the same and is continuous to the margin of the postclypeus (Pl. XXVIII., fig. 12, l.). The mandibles (Pl. XXVIII., figs. 7, 8, 9, m.) are hinged to the dorsal plate of the beak at the juncture of the ante- and post-clypeus, and their lengths almost correspond to that of the anteclypeus. They are rather small and slender and can cross with each other freely. They are relatively longest in *Bittacus*, in which each is armed with a single sharp tooth. Next comes that of *Panorpa*, in which there are two teeth. *Panorpodes* has the shortest mandibles, which are dilated towards the apex and are furnished with one rather sharp, and another very small tooth. The maxil-

lae (Pl. XXVIII., figs. 16, 17, 18, *mx.*) are rather complex. Each cardo (*ca.*) is a somewhat triangular piece and is articulated to the post-gena (*pg.*) at the base of the beak (see Pl. XXVIII., figs. 2, 4, 6). The stipites (*st.*) are slender pieces laterally bordering the submentum (*sub.*), forming with it the underside of the beak; their comparative lengths differ in the three genera; in *Panorpa* they are longest, in *Panorpodes* shorter and in *Bittacus* shortest (see Pl. XXVIII., figs. 2, 4, 6). The lacinia (*la.*) and galea (*ga.*) are, broadly speaking, represented by the form of two lobes, each lobe being very complex in structure. The inner lobe, that corresponds to the lacinia, is composed of the ciliated membranous ground-body framed with three chitinous supports (Pl. XXVIII., figs. 16, 17, 18, *la*<sub>1</sub>., *la*<sub>2</sub>., *la*<sub>3</sub>.), of which the outwardly situated one (*la*<sub>1</sub>.) is stout and dilated towards the apex. Both outer and inner edges of the lobe are provided with a row of bristles, of which the inner one is specially arranged in a manner peculiar to each genus. In *Bittacus* the internal support (*la*<sub>3</sub>.) is inconspicuous. The outer lobe, that corresponds to the galea, is composed of two chitinous supports, of which the outer one (*ga*<sub>1</sub>.) is the larger, and dilated at the apex. The inner support (*ga*<sub>2</sub>.) is very strange in structure, as it originates from the root of the inner lobe and fuses together with the outer support just mentioned. In *Bittacus* these two supports appear to be a single mass. The margins of the lobe are also fringed with hairs. Both the outer and inner lobes are decorated with beautiful tufts of hairs on the apex, which appear like the leaves of a palm-tree. The maxillary palpus (*mx. p.*) is very conspicuous and five-jointed. The palpi of both sides diverge from each other in *Panorpa*, run along the beak parallel in *Bittacus*, and are usually concave within in *Panorpodes*. The minute construction of the palpus is, however, different in the three genera. In *Panorpa* each joint is stout, slightly dilated towards the apex and almost equal in size except the basal second, which is slightly shorter on account of the presence of another small jointlet (Pl. XXVIII., fig. 16, *j.*) before it. If one takes this joint into consideration the maxillary palpus of *Panorpa* must have six joints. In *Panorpodes* the terminal three joints are subequal, the last largest of all, while the basal two taken together are equal to one of the others. Of these latter joints the basal second (*j.*) is very small, just like the extra-joint (Pl. XXVIII., fig. 16, *j.*) of *Panorpa*, so that if one does not count this as a true joint *Panorpodes*



has four maxillary palpal joints. In *Bittacus* the basal two are exceedingly small while the third is the largest of all, the fourth and fifth are moderate and subequal. The labial palpus (Pl. XXVIII., figs. 13, 14, 15, *l. p.*) is very conspicuous, consisting of two joints.\* In *Panorpa* and *Panorpodes* they are similarly constructed, the first joint densely ciliated with the exception of the basal piece (*bas. p.*), which is triangular in shape and of a thick chitinous texture. In *Bittacus* the basal piece is entirely absent and the two joints are similarly constructed, with rather few hairs, and far more slender than in the other two genera. To the palpus follows the palpiger (*pgr.*), which is bifid at the apex and is armed with some long bristles. In *Panorpa* the bristles are very scarce and a pair of very conspicuous setae are found on the side. The next portion which follows the ligula should be the mentum and submentum (Pl. XXVIII., figs. 2, 4, 6, 13, 14, 15, *men.*; *sub.*). The boundary of the two portions are not clearly defined, still there exists an inconspicuous transverse line (see figs. 3, 4, 5, 13), which I have adopted as a landmark in distinguishing the two portions. If this be correct the mentum is very short and the submentum very long, so that the greater portion of the underside of the beak can be said to be constructed mainly of the latter. The hypopharynx is a very small hollow body, different in shape in the three genera. It is situated near the articulation of mandibles to the head, rather anterior in position in the beak. In *Panorpa* (Pl. XXIX., fig. 7), the hollowness is very slight; it is only slightly concave dorsally, just like the apex of a spoon. The entire surface is densely covered with hairs which are very long at the apex. The lateral edges near the base are margined with a short narrow chitinous plate, deprived of hairs. The hypopharynx of *Panorpodes* (Pl. XXIX., fig. 8) is pouch-form, just like the hood of a cape, consisting of two triangular lobes, of which two edges are fused together. Dorsally it is entirely open. The anterior edge is fringed with thick hairs. *Bittacus* has the elongate bottle-like hypopharynx (Pl. XXIX., fig. 9), presenting an elliptical aperture on the dorsal side near the base. The entire surface is rather scantily haired, except the apex and the conspicuous median edge, which are covered with a few short hairs.

\* WESTWOOD and McLACHLAN propose 4 joints. Even if the chitinous basal piece be taken as an independent joint we can count only three joints.



## 2. THORAX.

The thorax consists of three segments: pro-, meso- and meta-thorax. The prothorax (*pro.*) is very small; its notum, the largest part, is a single plate, divided by some transverse lines into the four regions—praescutum (*sc<sub>1</sub>.*), scutum (*sc<sub>2</sub>.*), scutellum (*sc<sub>3</sub>.*) and postscutellum (*sc<sub>4</sub>.*) (see Pl. XXIX., figs. 1, 2, 3). The pleuron is very small; the episternum (*es.*) is a slender chitinous bow situated obliquely on the membranous part of the neck; the epimeron (*em.*) is a small triangular plate found near the lateral extremity of the notum, and is connected with the episternum by its ventrally directed end. The sternum is a longitudinal linear piece, smallest of all, situated ventrally between the coxae. The mesothorax (*meso.*) is a large mass; it is divided posteriorly by a transverse line into two portions. The anterior portion is far larger than the other and consists of four parts—anterior part (praescutum, *sc<sub>1</sub>.*), two lateral parts (scutum, *sc<sub>2</sub>.*) and posterior part (scutellum, *sc<sub>3</sub>.*). The posterior portion is very short and composed of a single mass, the postscutellum (*sc<sub>4</sub>.*) (see Pl. XXIX., figs. 1, 2, 3). The pleuron is of considerable dimension and bears a pair of fore wings and a small round patagium (*p.*); the episternum (*es.*) and epimeron (*em.*) are large, elongate sclerites. To the former the large elongate coxa (*cx.*) is attached and to the latter a large supporting piece, which is known by the name of meron or trochantine (*me.*) (see Pl. XXIX., figs. 4, 5, 6). The sternum is continuous with the pleuron and represents a †-formed chitinous ridge. Between the pro- and meso-thorax there is a pair of spiracles (*sp.*). The metathorax (*meta.*) is almost similarly constructed as the mesothorax. Between the two segments there is a second pair of spiracles (see Pl. XXIX., figs. 1-6, *sp.*).

## a. Legs.

The legs are slender, composed of coxa (*cx.*), trochanter (*tr.*), femur (*f.*), tibia (*tb.*) and tarsus (*ts.*) (see Pl. XXIX., figs. 4, 5, 6, 10, 11, 12). As already stated there is another piece along the coxa called meron (*me.*). In *Bittacus* the legs are so slender that they look very much like those of a crane-fly. The tibia bears two conspicuous apical spurs (fig. 11, *spu.*), which are especially long in *Bittacus* (see fig. 10, *spu.*). The tarsus is five-jointed, the last joint of which bears a pair of claws in *Panorpa* and *Panorpoles*, and a single claw in *Bittacus*; in the former case there is a pulvillus (*pul.*) between

the claws. The claws of *Bittacus* and *Panorpodes* are simple and not pectinate (Pl. XXIX., fig. 12 a; text-fig. 2, y) while those of *Panorpa* are highly pectinate (text-fig. 2, a-x). As the claws in *Panorpa* are very variable in form, some authors paid attention to them for taxonomic purposes; RAMBUR attached considerable importance to the number of teeth. However, the number is never fixed in a species, as it may differ in individuals of the same species or be equal in different species. Recently ENDERLEIN utilized the morphology of the claws as one of the generic characters in distinguishing his new genus *Aulops* from the old genus *Panorpa*, saying of the claws of *Panorpa* "fast auf der ganzen Unterseite gezähnt," while for *Aulops* "Klauen nur in der Basis gezähnt." Though by the form of claws the genera *Panorpa*, *Panorpodes* and *Bittacus* are distinguished, we can never separate the two genera *Aulops* and *Panorpa* by the above stated character. Indeed the peculiarities noticed by ENDERLEIN occur in both genera. However, as is explained later, *Aulops* is in many respects very doubtful for its generic value. But if the morphology of the claws does not hold good in that case, we see, at any rate, it is of great use in distinguishing the other genera. My own observations lead to the conclusion that the morphology of the claws for specific purposes is never without use, though it cannot be considered as a fixed character for each species, being often subjected to much variation. For that reason I have recorded in the systematic part the morphology of the claws as one of the supplementary characters.

Speaking generally, the claw of *Panorpa* is a comb, dorsally with a curved main body, which bears ventrally many elongated teeth (see text-fig. 2, a-x). Of the curvature of the dorsal body, and the forms and number of teeth I have made the following observation:—

1. Dorsal body strongly curved, as in

*gokuensis*, *japonica*, *rectifasciata*, *wormaldi*, *striata*, *klugi*, *trizonata*, *ochracea*, *ochraceopennis*, *lewisi*, etc.

Or less strongly curved, as in

*cornigera*, *communis*, *arakavae*, *pulchra*, *bicornuta*, *hakusanensis*, *pryeri*, *leucoptera*, *multifasciaria*, *takenouchii*, *nikkoensis*, *obscura*, etc.

2. Apex of dorsal body produced over the teeth, as in

*cornigera*, *communis*, *arakavae*, *japonica*, *pulchra*, *bicornuta*, *hakusanensis*, *leucoptera*, *striata*, *nikkoensis*, *obscura* (scarcely), etc.

Text-figure 2.—left-side claw of the left fore leg.  $\times 86$ .

- |                                    |                               |                          |                               |
|------------------------------------|-------------------------------|--------------------------|-------------------------------|
| a, <i>Panorpa cornigera</i> .      | b, <i>P. communis</i> .       | c, <i>P. gokaensis</i> . | d, <i>P. arakavae</i> .       |
| e, <i>P. japonica</i> .            | f, <i>P. pulchra</i> .        | g, <i>P. pulchra</i> .   | h, <i>P. rectifasciata</i> .  |
| i, <i>P. bicornuta</i> .           | j, <i>P. hakusanensis</i> .   | k, <i>P. pryeri</i> .    | l, <i>P. leucoptera</i> .     |
| m, <i>P. wormaldi</i> .            | n, <i>P. multifasciaria</i> . | o, <i>P. trizonata</i> . | p, <i>P. takenouchii</i> , ♂. |
| q, <i>P. takenouchii</i> , ♀.      | r, <i>P. nikkoensis</i> .     | s, <i>P. striata</i> .   | t, <i>P. klugi</i> .          |
| u, <i>P. ochraceopennis</i> .      | v, <i>P. obscura</i> .        | w, <i>P. lewisi</i> .    | x, <i>P. ochracea</i> .       |
| y, <i>P. Panorpodes paradoxa</i> . |                               |                          |                               |

Or produced only as long as the teeth, as in

*gokaensis*, *rectifasciata*, *pryeri*, *wormaldi*, *multifasciaria*, *takenouchii*, *klugi*.\*

3. Each claw may bear four prominent teeth (excluding one or two small basal teeth and the apex of main body itself), as in

*cornigera*, *communis*, *gokaensis*, *arakavae*, *pulchra*†, *bicornuta*, *hakusanensis*, *pryeri*, *leucoptera*, *wormaldi*, *multifasciaria*, *takenouchii*, *nikkoensis*, *klugi*, etc.

\* Frequently produced over the teeth.

† Three or four occur in this species.



Or may bear three teeth, as in

*japonica*, *pulchra*,\* *rectifasciata*, *striata*, *trizonata*, *ochracea*,  
*obscura*, *ochraceopennis*, *lewisi*, etc.

4. Apices of teeth are usually sharply pointed, but in certain species such as *ochraceopennis*, *ochracea*, *lewisi*, etc., they are blunt.

These above stated facts, however, are subject to much variation and cannot be looked upon as fixed characters, though in widely separated species they may often be of great use to the systematic worker.

Further, the claws are variable even in legs of the same individual as well as in the right and left of the same leg.

The legs of *Panorpa* and *Panorpodes* are fitted for walking or resting on a leaf, while that of *Bittacus* are adapted for catching other insects. Besides, they are used in hanging down from a twig or a leaf. For this reason, the fourth and fifth joints of the tarsus are furnished with a row of specially formed teeth along the internal margin (Pl. XXIX., fig. 12 a, 12 b). The teeth of the fourth tarsal joint are each of ovate form so that the margin of joint becomes crenate (fig. 12 b). The teeth of the fifth joint are each of a triangular shape, with the base outermost, forming the internal margin of the joint, so that it appears entire and very sharp, like the edge of a sword (fig. 12 a). The number of these teeth are not fixed; they may vary in individuals of the same species as well as in legs of the same individual. In one specimen of *Bittacus nipponicus*, the fourth joint contained 32 and the fifth 15 teeth, and in another case the former 30 and the latter 25.

#### b. Wings.

Typically, there are two pairs of wings—the fore and hind wings. They are membranous, naked, long and narrow, with moderate reticulation. The fore pair is slightly longer than the hind one, which is, in repose, covered by the former, and the two are carried on the body nearly longitudinally. Most species of *Panorpa*, and a few of *Panorpodes* and *Bittacus* bear some black markings consisting of fasciae or spots. The peculiarities of the venation of wings and arrangement of wing-markings are explained in detail under their own headings.

\* Three or four occur in this species.



## 3. ABDOMEN.

The abdomen is elongate, conico-cylindrical in *Panorpa* and *Panorpodes* and cylindrical in *Bittacus*, and is composed of ten segments. In the male of *Panorpa* and *Panorpodes* formerly eight abdominal segments were given and at present, so far as I know, many authors seem to agree in recognizing nine segments; in *Bittacus* however, ten segments are usually counted. I am of the opinion that ten segments are present in the males of *Panorpa*, *Panorpodes* and *Bittacus* as in the females of them. The reason will be explained further on.

The first abdominal segment in these three genera is very small and fused with the postscutellum of the metathorax, so that it appears to constitute a single piece with this, from which, however, it can be distinguished by a transverse line. It consists chiefly of notum and pleural membranes. The former is a transversely placed chitinous bow and the latter are small triangular membranes laterally placed, which bear a pair of conspicuous spiracles (first abdominal spiracle). The sternum is almost invisible, and consists of a pair of very narrow transverse chitinous pieces. Owing to this modification the segment was formerly overlooked and in that time eight segments only were recognized in the male.\* The second segment is cylindrical, composed of notum, sternum and pleural membranes, which bear a pair of spiracles (second abdominal spiracle) (see Pl. XXIX., figs. 16-21). In *Panorpa* and *Panorpodes* this segment is rather short, while in *Bittacus* it is moderately long. The third abdominal segment is almost similarly constructed as the second, but in the majority of males of our species of *Panorpa*, the notum is more or less posteriorly produced in the middle. In *Panorpa klugi*, *P. japonica*, etc., this production is rather short and broad, and covers only the anterior portion of the fourth segment, while in *P. takenouchii* and *P. sauteri* it is produced to a great extent, in the former reaching the eighth segment and in the latter the sixth. In *takenouchii* it is tube-form, the ventral side being densely fringed with long hairs (Pl. XXIX., fig. 15). In *P. klugi*, etc., the ventral surface of the dilated portion is also densely covered with hairs (see Pl. XXX., figs. 11 b, 11 c). The fourth segment is almost like

\* Of course nine segments were recognized in the female.

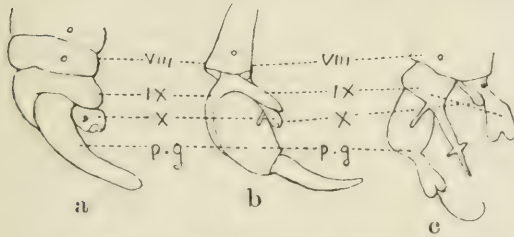
the preceding one (it is somewhat conical in the female of *Bittacus* when the eggs are ripe). In the male of those species which bear the posterior lobe on the third abdominal segment, there is a small projection near the anterior margin of the fourth, corresponding to the dilated portion of the former segment and concealed under it (Pl. XXX., fig. 11 a). The projection is, in *takenouchii*, placed rather near the posterior margin; it is also covered with long hairs. As these organs are entirely wanting in females it would very probably be of a secondary sexual character; according to FELT it secretes "a volatile oil attractive to the female." The fifth is like the preceding. The subsequent segments differ in the two sexes.

Male:—In *Panorpa* the sixth segment is cylindrical and far longer than the preceding. It is uniformly of a chitinous structure so that the distinction of notum, sternum and pleural membrane is entirely obscured. In *cornigera*, *galloisi*, *gokaensis* and *arakavae* there is a short process at the posterior margin (Pl. XXIX., fig. 14 a), which comes closely in contact with the seventh segment when the latter is erected, where there exists a median depression to receive the process. (The depression is indicated with x in Pl. XXIX., fig. 14 b). As this construction is also only found in males it would possibly be of secondary sexual character. The first eight segments bear spiracles, which together with the two on the thorax, makes ten pair in the three genera. The eighth is similar to the preceding segment, but more slender and commonly narrowed at the base. Next to this segment there is an intermediate portion forming the dorsal and ventral appendages\* (Pl. XXIX., figs. 18, ix., Pl. XXX., fig. 10). The dorsal appendage is in most species almost similarly formed; it is a long, densely ciliated, chitinous plate with a round apex (Pl. XXX., figs. 5 a; 10, *d. ap.*). In *cornigera*, however, it is deeply sinuate in the middle, so that it presents the form of an U (Pl. XXX., fig. 13 b). In *wormaldi* the apex is slightly sinuate (Pl. XXX., fig. 21). The ventral appendage† (*v. ap.*) is a forked plate, with a stalk and two branches and far larger than the dorsal appendage. It is very variable in shape, which is in certain cases peculiar to species, so that most systematists pay special atten-

\* As the insect usually bends up its abdominal extremity the dorsal appendage is situated ventrally and the ventral one dorsally.

† Some authors call the dorsal appendage "gonopoda."

tion to it. Thus, for example, in *japonica* the stalk is rather long, with two branches diverged outwardly forming a Y; in *klugi* the branches are slightly longer and are converged towards the apex; in *cornigera* the stalk is very short and the branches are almost parallel with each other. These and many other forms are respectively described in the systematic part. The above stated dorsal and ventral appendages constitute together a single sclerite, so that we can separate it as a single piece from the other segments (Pl. XXX., fig. 10). As in the pupal stage this portion is very conspicuous, and represents the same dimensions as the other segments, I am of the opinion that, though in imago it is rather obsolete, it represents the true ninth segment and, of course, it still constitutes an independent segment. Under the dorsal appendage there is a slightly narrower and shorter tube, ventrally furnished with a hairless, chitinous plate (Pl. XXX., fig. 5 b, *c. pl.*). This tube bears a pair of cerci (*cer.*) with a few hairs on the apex, stretching out laterally beyond



Text-figure 3.—Last abdominal segments ( $\times$  about 7): a, *Panorpa* (pupa); b, *Panorpa* (adult); c, *Bittacus*; VII—x, number of abdominal segments; p.g., pedes genitales.

the sides of the dorsal appendage, so as to be visible when viewed dorsally (see Pl. XXX., fig. 5 a). This tube encloses a still smaller tube which is usually telescoped into the former. It bears an opening (fig. 5 b, *a.*) at the extremity with crenate margin,

which is the anus. This inner tube is usually covered with rather long hairs. The portion of body, consisting of these two tubes on which lies the anus, should be considered as the tenth segment, though it is rather inconspicuous in adult insects. In the pupal stage it is more prominent than in imago. If my assumption be admitted, the next large segment (cheliferous segment), that forms the basal portion of the forceps, should be looked upon as the additional genital segment, to which KLÁPALEK gives the name of *pedes genitales*. It is usually very stout and conceals the genitalia, which are covered by the ventral appendage of the ninth segment. This way of orientation appears to be more reasonable when we compare *Panorpa* and the other two genera, *Panorpodes* and *Bittacus*, in which most authors recognize nine



segments in the former and ten in the latter, taking moreover the above stated additional segment wrongly as the ninth. This consideration of mine seems to agree, to a certain extent, with the statement of KLÁPALEK, but I am not certain whether his conclusion was based on the result of development. These points are demonstrated in text-figure 3. The additional genital segment is bilobed towards the extremity and bears forceps or chelae (Pl. XXX., figs. 1-4), which are inwardly curved, strong, chitinous bodies bearing an indentation or elevation on the internal edges. The chelae constitute in the imago the special joints and are articulated to the genital segment, but in the pupal stage they form a single portion with the latter, so that the differentiation must have occurred for the first time at the beginning of the imaginal stage.

In *Panorpodes*, the sixth segment is similar in size and shape to the fifth, so that there are pleural membranes present, whereas in *Panorpa* the fifth is shorter than the sixth and the pleural membranes are absent. The seventh is slightly shorter than the preceding, and the region where the pleural membrane should appear is indicated by a longitudinal line. The eighth segment is much smaller and obliquely truncate. These three segments are gradually narrowed. The ninth segment is represented by the dorsal and ventral appendages as in *Panorpa*. The dorsal appendage (Pl. XXXI., fig. 8 b) is almost like that of *Panorpa*, but the apex is slightly sinuate in the middle. The ventral appendage (Pl. XXXI., fig. 8 a) is very conspicuous, its branches moderately curved, bearing on their apices each a dentate chitinous triangular plate. The tenth (anal tube) (Pl. XXXI., figs. 5 a, 5 b) under the dorsal appendage is very short, membranous, the cerci are very short, stout and covered with hairs. The internal tube is like that of *Panorpa* very small and hairy, with the apex crenate. The additional genital segment that forms the basal portion of the forceps is very large and stout, while the chelae are very short and small. In the general construction there is no great difference between *Panorpa* and *Panorpodes*.

In *Bittacus* the sixth segment is shorter than the fifth and conico-cylindrical, the seventh still shorter, thickened towards the extremity, the eighth still more short. These three segments, like the preceding, consist of three parts, viz. notum, sternum and pleural membranes. The ninth and tenth are well modified. Of the former, the sternal half only is developed to constitute the



segment, the notal half forming a very broad dorsal appendage (Pl. XXXI., figs. 3, 4, *d. ap.*), the form of which is variable in species and is used for taxonomic purposes. This may be homologous to the dorsal appendage of the other two genera. Within the appendage near the base there is a cylindrical body, corresponding to the tenth segment, on which lies the anus (Pl. XXXI., figs. 3, 4, 6, *a.*) The ninth body-segment has posteriorly a conspicuous uncus variable in species (figs. 3, 4, *un.*). Still posterior to the ninth segment there is the additional segment, which bears the genitalia, as in *Panorpa* and *Panorpodes*. In order to explain more in detail I will describe that of *Bittacus nipponicus*. In this species the uncus on the ninth (Pl. XXXI., figs. 3, 4, *un.*) is a long chitinous rod, attenuate at the apex, where it is armed with hairs. Near the apex it bears a pair of short lateral arms with many hairs, so that the entire rod appears like a cross. At the posterior basal side of the uncus two lateral appendages (*l. ap.*) arise, which are rather slender rods with some ciliation. Between these there occurs in the middle an unpaired middle appendage (*m. ap.*), which is very slender and attenuate towards the apex. The additional segment bears on its dorsum a flat hairless chitinous Y-shaped plate (Pl. XXXI., figs. 3a, 3c, 4, *p. p.*),\* from the base of which, through the median axis, there arises a filiform chitinous filament, which is extended dorsally beyond the appendage, and the terminal portion is usually coiled up like the proboscis of a butterfly. The homology of these portions can be seen in text-figure 3 (page 281).

In conclusion I may say, that my recognition of ten segments in *Panorpa*, *Panorpodes* and *Bittacus* appears more reasonable when we compare them with one another.

Female:—The sixth abdominal segment in *Panorpa* and *Panorpodes* is conico-cylindrical, and in the latter genus it is twice the length of the fifth. In *Bittacus* it is cylindrical. The seventh to the tenth in *Panorpa* and *Panorpodes* are cylindrical and more slender than the sixth and the greater portion of each segment is telescoped into its preceding segment (Pl. XXIX., figs. 7, 9). In *Bittacus* the seventh is almost similar to the sixth, the eighth very short, ninth and tenth still shorter, each telescoped into its preceding segment (Pl. XXIX., fig. 21). The seventh and eighth in *Panorpa* are composed of

\* "Inner harpe" of FELT.

notum, sternum and pleural membranes which connect them, and in the latter there lies in each segment a pair of elongate chitinous plates (see Pl. XXIX., fig 7 b). In *Panorpodes* the two segments are membranous and posteriorly dilated, and each segment is framed by three dorsal, one lateral, and two ventral, longitudinal chitinous stripes (fig. 19). The ninth segment of *Panorpa* is peculiarly constructed. The sternal portion\* is free from the dorsal portion of the segment and attached to it only anteriorly by a membrane (Pl. XXX., fig. 6, *s. p.*). It is subtriangular in form, composed of two spindle-shaped plates which are connected by a membrane (Pl. XXX., fig. 8). The notum of the ninth segment alone constitutes the segment, the pleural membranes forming the ventral floor (Pl. XXX., fig. 6, *IX*). In *Panorpodes* the ninth is far smaller, membranous, and supported by two dorsal and two ventral chitinous stripes (Pl. XXIX., fig. 19). In *Bittacus* the ninth is conico-cylindrical, and on the ventral surface there are two subtriangular hairy plates meeting posteriorly along the median line, and partly overlap the ventral portion of the segment (Pl. XXXI., fig. 2 *tr. p.*).† The tenth segment in *Panorpa* consists of two joints; the basal true joint is an entirely chitinous, cylindrical body, which is followed by the membranous joint. This latter joint bears dorsally a forked appendage, which consists of the basal portion (Pl. XXX., figs. 6, 7 a, 7 b.) and the paired, two-jointed branches (*a. br.*). Ventrally there is a small chitinous plate covered with hairs (fig. 6, *s. c.*). Posteriorly opens the anus (*a.*) which is surrounded by rows of hairs. In *Panorpodes* the tenth segment consists of two membranous, conico-cylindrical joints, of which the latter bears a two-jointed appendage (*a. br.*), which is far smaller than that of *Panorpa* and does not possess the basal portion (see Pl. XXXI., fig. 9b). In *Bittacus* the tenth is composed likewise of two joints, of which the terminal one bears laterally a pair of solid seta-form appendages (Pl. XXXI., fig. 2, *a. br.*) which are armed with specially formed hairs, the base of each being furnished with a cup-like envelope (see Pl. XXXI., fig. 2, *a. br.*, figs. 6, 7). Such hairs were not found on the appendages of *Panorpa* and *Panorpodes*. The anus (fig. 2, *a.*) is situated posteriorly and is covered by a dorsal and a ventral plate (*v. p.*),

\* Some authors call this "subgenital plate."

† To this some authors give the term "subgenital plate."

of which the former has a slightly sinuated margin.

I found seven pairs of the abdominal spiracles in *Panorpa*, six pairs in *Panorpodes*, and eight pairs in *Bittacus*.

The general appearance of the abdomen of the female varies somewhat according to the degree of maturation of the eggs.

#### a. Genitalia.

The investigation of genitalia in Panorpidae is undoubtedly very difficult, because the results given by the various authors do not agree, even in the principal parts. The most detailed work on the subject is possibly that of STITZ, who made his studies on *Panorpa communis*, *Boreus* and *Bittacus*. Though in the anatomy of the internal organs there is no great difference between *communis* and most of our species, the external morphology of genitalia is in both widely separated—indeed it varies in many ways even amongst our species.

The male genitalia:—In *Panorpa klugi*, there is an oval, membranous region under the ventral appendage of the cheliferous segment of the male. If one presses the segment laterally there evaginates a yellowish five-lobed vesicle—*anterior\** two lobes, large and well differentiated, the middle one oval and the posterior two small (Pl. XXX., fig. 1, *v.*). The posterior lobes bear a pair of slender, linear, chitinous unci (*un.*) at their sides. Posteriorly to the lobes, between the unci just mentioned, there arises a pair of pyramidal chitinous harpes† (*har.*) uniting tightly along the body axis so that they appear like a single pyramid with a broader base. Each harpe has elevated ridges and the apex is slightly truncate and bears a small indentation. Dorsal to these harpes there is a solid chitinous pyramid (*c. py.*), with three angles at the apex. Lateral of the pyramid, firmly rooted on a chitinous plate, there arise a pair of appendages (*l. ap.*), which are linear, chitinous stripes, dilated at the apex, where they appear membranous. Between the appendages there is a pair of vesicular bodies (*c. v. b.*) with much dilated apex, which contain a number of hairs. The dilated portions bend towards the body axis and are almost in contact with each other. All

\* Attention is called to the fact that the figure, for convenience sake, is drawn in a contrary direction.

† These correspond to the "blattartige Anhänge" of STITZ in *Panorpa communis*.



these parts mentioned constitute, so to say, a single mass and are situated at the middle of the cheliferous segment, between the bases of the chelae. The mass is internally supported by an U-shaped chitinous internal skeleton (*i. s.*), the lateral arms of which run along the sides of the mass and join the chitinous plate, situated at the base of the lateral appendages already mentioned.

Now the question arises, which of these bodies is properly to be considered as the penis? To this question only a few of the many investigators of the reproductive system of *Panorpa* give a definite answer.\* DEGEER thought the above stated eversible vesicle to be the penis, saying "Drückt man den Knoten von oben, so tritt ein kleiner, länglich ovaler, häutiger Teil hervor, der mit einer Art Kopf endigt, welcher aus einer an der Wurzel der Zange liegenden Öffnung heraustritt, unstreitig der Geschlechtsteil des Männchens."† Even the authority STITZ, if my understanding of him be correct, thought the same vesicle to be the penis, as he says: "Die beiden seitlich vom Septum liegenden Hohlräume enthalten jeder ein Gebilde, das, seinem Bau nach zu schliessen, ausstülpbar sein muss, also als Penis bezeichnet werden kann."‡ BRANTS, on the contrary, did not detect the penis in *Panorpa*, saying: "Ich habe indessen von einem Penis, der durch Muskeln bewegt wird, nichts entdecken können. . . . Es könnte auch möglich sein, dass bei *Panorpa* kein Penis notwendig ist, da die Einrichtung in der Zange derartig ist, dass in derselben zwischen dem weissen Körper und dem Darm ein leerer Raum bleibt, gross genug, dass das Weibchen das Aussenende seines Körpers hineinbringen kann."§

LOEW, who worked on the internal organ minutely, did not explain the external parts. FELT, who has figured the genitalia of *Panorpa* and *Bittacus* in the plate accompanying his work, did not give a detailed explanation of each part. To make the question clear it undoubtedly requires a careful investigation, both anatomical and embryological. However, from the observation of copulation, I can say that all the parts already described, except the eversible vesicle, just referred to, should be considered as the copulatory organ of the male,

\* In the following quotation KLÁPALEK's paper is omitted, as I could not read Bohemian, in which it is written.

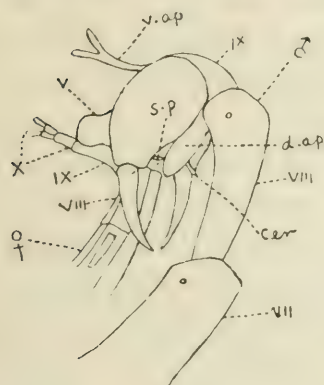
† I follow STITZ's quotation in Zool. Jahrbuch. anat. Bd. 26 (1906), p. 538.

‡ l.c. p. 548.

§ l.c. p. 536 (STITZ's quotation).



since in pairing almost all these parts seem to be put into the female sexual opening of the ninth segment, the sternal division of that segment of the



Text-figure 4.—Last abdominal segments of the two sexes in copulation (*Panorpa klugi*).  $\times$  about 9.

female, at that moment, being deeply protruded under the dorsal appendage of the male (see the text-figure). (During copulation the male constantly moves the dorsal appendage.) The greater portion of the eversible vesicle, which was thought by many authors to be the penis, does not penetrate into the opening, but protrudes posteriorly, so as to press the abdominal extremity of the female in such a manner as to cause it to bend upward nearly at right angle to the rest of the abdomen (see text-figure 4, *v.*). It is therefore certain that the vesicle is not the true penis.

The genitalia of *cornigera*\* (Pl. XXX., fig. 2) are quite different from that of *klugi* and nearer allied to the European forms. In it the unci (*un.*) are very conspicuous and dorsally between them there is a pair of bifid chitinous harpes (*har.*).† In *pryeri*‡ (Pl. XXX., fig. 4), the unci (*un.*) are also very conspicuous. Between them at their base there is a pyramidal chitinous harpes (*har.*) rather resembling that of *klugi*. Dorsal to it there is a pair of small cylindrical bodies (*c. b.*). Still dorsal and lateral to these there is a pair of chitinous pieces (*c. pie.*), behind which there is a semicircular chitinous plate (*c. pl.*) composed originally by the union of two quadrants. Posterior to the plate there is a pair of much dilated vesicular bodies (*c. v. b.*). In the dried specimen of *takenouchii* (Pl. XXX., fig. 3) we see a pair of V-shaped unci (*un.*), the internal branch of each being crossed over each other, showing the form of a W. The pair of cylindrical bodies described in *pryeri* is in this species very conspicuous and fills up the entire area between the chelæ (see Pl. XXX., fig. 3, *c. b.*).

In *Panorpodes*§ there is a pair of whitish, posteriorly directed tubercles

\* Observations were made on macerated dried specimens.

† "Blattartige Anhänge" of STITZ.

‡§ Observations were made on macerated dried specimens.

(Pl. XXXI., fig. 1, *v.*), possibly corresponding to the eversible vesicle of *Panorpa*. Dorsal and posterior to them there is a pair of large ovate vesicular bodies (*c. b.*), closely in contact with each other along the body axis. This may be homologous to the central cylindrical body of *Panorpa*. Ventrally we can see through the bodies a pair of irregular chitinous harpes (*har.*), which may be equal to the same in *Panorpa*.

The appendages of male genitalia of *Bittacus* are already explained. In *Bittacus nipponicus*\* there is dorsally an unpaired uncus (Pl. XXXI., figs. 3, 4, *un.*), which bears at the base a single middle, and paired lateral, appendages. Posterior to the uncus there is the Y-shaped posterior chitinous plate or harpe (*p. p.*), at the root of which, indicated by *p* in figures 3a and 3c the genital duct may possibly open. Whether this entire body serves as the penis or not is not yet ascertained. At the root of the plate there is a pair of chitinous rods dilated at the apex (Pl. XXX., fig. 3c, *c. r.*).

The female genitalia:—The female opening is situated in the ninth abdominal segment. In *Panorpa* the ventral portion† of the segment is separated posteriorly from the dorsal portion and constitutes the sexual opening (see Pl. XXX., fig. 6). Inwardly to the opening there is an U-shaped, chitinous internal skeleton (Pl. XXX., fig. 6, *i. s.*, fig. 9), into which the genital ducts open. In *Panorpodes* (see Pl. XXXI., fig. 9b) the ninth segment is cylindrical and not separated into dorsal and ventral portions like *Panorpa*, so that the genital aperture may probably open between this segment and the next. *Panorpodes* has also the internal skeleton (fig. 9a) situated at the base of the ninth segment. This internal skeleton is smaller than that of *Panorpa* and consists of a single quadrate mass originally composed of two elongate chitinous pieces. In *Bittacus* (Pl. XXXI., fig. 2) the opening is situated under the two ventral triangular plates (*tr. p.*).‡

## II. Internal Structure.

### 1. DIGESTIVE SYSTEM.

The alimentary tract in *Panorpa*, *Panorpodes* and *Bittacus* is almost

\* Observations are made on macerated dried specimens.

† Some authors use the term "subgenital plate" for it.

‡ Some authors call the plates "subgenital plates."

similar. It is a long and rather simple tube. The oesophagus (Pl. XXXII., fig. 3, *oe.*) is a rather narrow tube, supported at two points by a bundle of muscles (*m. pt.*), where the canal is also twice dilated. The anterior one is fringed anteriorly with a circular chitinous frame-work (fig. 9, *c. f. w.*), on the ventral spot of which there arises a chitinous rod, which runs forward along the ventral side of the oesophagus, lining the floor thereof. The oesophagus then leads to an elliptical organ considered as the proventriculus (*pv.*). The internal structure of this organ is very peculiar and has already been anatomically described by LOEW\* and DUFOUR† in *Panorpa communis*. I have studied it histologically in *Panorpa klugi*, *P. japonica*, *Panorpodes paradoxa* and *Bittacus nipponicus*, and have found that it is similarly constructed in these species of different genera. On examining the organ superficially a dark, hard looking cylindrical body can be seen through the tissue. On the top and bottom of the body we see a semi-spherical lumen which is connected with the cavity of the alimentary canal. The cylindrical body in *Panorpa* is comparatively long and in *Panorpodes* and *Bittacus* rather shorter. However, even in *Panorpa* the length is frequently variable. The dark appearance of the body is caused by the presence of specially arranged long setae. As can be seen from the radial and transverse sections (Pl. XXXII., figs. 5, 6), on the internal wall of the organ a great number of long setae arise, directed to the central axis of the organ, and mostly horizontally. The length of the setae is not strictly fixed. I have measured 0.16 mm.—0.18 mm. As can be seen from Pl. XXXII., fig. 4, the setae (*se*) arise from the single layer (*ep.*) of epithelial cells, which is outwardly surrounded by a number of longitudinal muscles (*l. m.*). These muscles appear in sections as many polygonal bodies with central or excentral nuclei. Still outwardly there is a layer of ring muscles (*r. m.*), which forms the outer wall of the proventriculus. Each seta is a straight chitinous rod and almost testaceous; only the basal part is blackish brown and for a short distance beyond colourless. LOEW, who mentioned the root of the seta colourless, might have referred only to that region. The connection of the setae to the body wall, that LOEW failed to observe, as far as I could make out, is simply the attachment of the former

\* Linn. entom., iii, 1848, p. 36.

† Mem. Ac. Sci. étrang., vii, 1841, p. 582 (after SHARP).



to the epithelial layer, and there seems to be no intimate connection with the epithelial cells. The basal portion of the seta is slightly dilated giving the form of a flask.

Next to the proventriculus there comes a simple tube of a large caliber, which is the mid-intestine or stomach (Pl. XXXII., fig. 3, *mi.*). Immediately behind the proventriculus it is slightly constricted and then gradually begins to dilate posteriorly so as to form the widest part of the alimentary canal, which again posteriorly becomes narrow and passes into the hind intestine (*int.*). Near the posterior end of the mid-intestine the dark-brownish Malpighian tubes (*m. p. tb.*) open, which are six in number and lie alongside the stomach in a complex manner. The basal parts of the tubes are colourless. The hind-intestine (*int.*) is rather slender, beginning at the posterior end of the stomach; it runs posteriorly for a while and then turns forward for a short distance, then again curves posteriorly and runs a long way to the anus. Before the anus there is a dilate portion known as the rectum. Anteriorly to the rectum there is a constricted portion which may probably be referred to as the colon.

Salivary glands (Pl. XXXII., fig. 9, *s. g.*) are rather small, situated dorsally on the oesophagus, where the latter is bent from the head to the thorax. (In the figure the glands are turned aside.) The glands consist of a pair of long, white, granular-looking tubes situated side by side, which basally narrow into fine filaments that rest on the wall of the alimentary canal. I did not succeed in tracing how each salivary duct opens into the oesophagus, where, according to LOEW, they open by a common duct.

Fat-bodies\* are just as in many other insects and occur in abundance in the body cavity. What LOEW says on the European species "in der Regel nur sparsam vorhanden" is not applicable to our common species.

## 2. NERVOUS SYSTEM.

The investigation of the nervous system is extremely difficult. I have not yet succeeded in tracing the nerves arising from each ganglion in a satisfactory manner. The following are the results that I arrived at from a study of the female of *Panorpa klugi*. The brain is a large, transversely

\* For convenience I append the description of fat-bodies here.



elliptical mass which bears laterally a pair of large spherical optic lobes. The thoracic ganglia are large and three in number (I have, however, in two examples discovered only two ganglia, the prothoracic one being wanting). The abdominal ganglia are smaller than the thoracic ones and six in number. This well agrees with the facts described by LOEW from a study of the European species. The first abdominal ganglion is in the thoracic segment, just behind the last thoracic ganglion. The second lies on the anterior margin of the third abdominal segment. The third to sixth lie respectively on the fourth to seventh abdominal segment. From the thoracic ganglia many nerves arise, and from the abdominal ganglia, with the exception of the last one, two pairs of nerves arise. The commissures connecting each ganglion run usually in distinct pairs side by side. Between the brain and the first abdominal ganglion however, they are slightly separated from each other. This differs slightly from the observation of LOEW in *Panorpa communis*; he shows in his plate the commissures between the brain and the prothoracic ganglion as fused together, though between the latter and the first abdominal ganglion they are separated just as in our species.

### 3. REPRODUCTIVE SYSTEM.

Male organs:—In *Panorpa* and *Panorpodes* the testes are situated in the sixth abdominal segment. In a few cases, however, they extend over the seventh. In *Bittacus* they extend from the sixth to the eighth abdominal segment. Each testis (Pl. XXXII., fig. 2, *t.*) is ovate, rather pointed towards the upper apex, and is purplish, or ochreous-brown in colour. In *Panorpa* and *Bittacus* it is elongate and in *Panorpodes* very short (see Pl. XXXII., fig. 7, *t.*), so that in the latter it looks like a nut. Each testis consists of three follicles arranged side by side round a longitudinal axis. In *Panorpa* the posterior end of the testis is filled up with a mass of much convoluted duct, the vasa efferentia (Pl. XXXII., fig. 2, *v.e.*). This latter often forms a single mass with the follicles or, as shown in the figure, becomes smaller and placed at the base of the follicles. In *Panorpodes* the vasa efferentia are separated by a short duct from the testis and form a larger oval mass (Pl. XXXII., fig. 7, *v. e.*). Each of the vasa efferentia is connected by a short duct, the vas deferens, with the vesicula seminalis (Pl. XXXII., fig. 2, *v. s.*),

which is a whitish, elongate body, lying along the median line of the body. A pair of accessory glands (Pl. XXXII., fig. 2, *a. g.*) open into the vesicula seminalis at the base of the vasa efferentia. The upper half of the vesicula seminalis as well as the accessory glands in *Panorpa klugi* are very long, while in European species they are reported to be small elliptical bodies. In our *wormaldi* the glands are also small. Possibly their lengths may vary according to the lengths of the segment in which the glands are contained, because that segment is comparatively longer in *Panorpa klugi* than in *wormaldi* and the European species that were examined.

Female organs:—My observations are on *Panorpa* and *Panorpodes*, which are almost similar. In *Panorpa klugi*, each ovary (Pl. XXXII., fig. 1, *ov.*) consists of ten ovarian tubes, as STITZ and GROSS observed in the European species, and not twelve, as BRANT and LOEW stated on the same species, nor twenty five as FELT reported in the American species. In each tube I could count 8–12 distinguishable eggs, the actual number being still greater. Each tube opens by a short stalk into the oviduct (Pl. XXXII., fig. 1, *ovd.*). Two to three or more eggs of each tube (usually in the anterior tubes two and in the posterior three or more) nearest to the oviduct mature simultaneously. Next to these follow some undeveloped eggs and then come still less developed eggs, until they finally pass into the terminal filament, which is rather long and runs anteriorly. It is but rarely, that the eggs in each tube are not successively developed, as just described. The oviducts unite and form the common oviduct (Pl. XXXII., fig. 1, *ovd. c.*), which terminates at the sexual opening (cloaca) of the ninth segment. Dorsal to the juncture of the oviducts the last abdominal ganglion is situated (Pl. XXXII., fig. 1, *l. a. g.*). Anterior to it there is a distorted pear-shaped sac (*bur.*), light-red in colour, which is known as the bursa copulatrix by STITZ and as the receptaculum seminis by LOEW. From the sac proceeds a slender, winding duct (*d.*), which terminates at the cloaca. According to STITZ, in the European species the terminal portion of the duct is forked shortly before it ends at the cloaca. Ventral to the oviduct there is a pair of long, slender, winding ducts, which are the colleterial glands (*c. g.*). The two ducts join posteriorly and form a common duct which also terminates at the cloaca. In what relation all these ducts stand to the internal skeleton, already described, that is found

in the interior of the cloaca, could not be detected. STITZ made this partly clear in the European species.

### III. Venations and their Variations.

Speaking generally, scorpion-flies have the typical venation, consisting of costa (*c.*), subcosta (*sc.*), radius (*r.*), media (*m.*), cubitus (*cu.*) and anals (*an.*). These veins are connected by some cross veins. *C.* and *sc.* are single, *r.* has two branches,  $r_1$ . and the radial sector (*rs.*), which forks twice and constitutes  $r_2$ .,  $r_3$ .,  $r_4$ . and  $r_5$ .;  $r_2$ . usually divides once or twice so that it has two or three branchlets. Rarely, however, does  $r_3$ . also happen to fork, but when it does it may have two branchlets. *M.* divides twice dichotomously and  $m_1$ .,  $m_2$ .,  $m_3$ . and  $m_4$ . are formed. *Cu.* has two branches  $cu_1$ . and  $cu_2$ ., which are stalked for a distance from the base. *An.* are three in number,  $an_1$ .,  $an_2$ . and  $an_3$ ., which are shorter in progression. These can be seen typically in the fore wing of *Panorpa* and *Panorpodes* (Pl. XXXIII., figs. 2, 3, 4). In the hind wing of the above genera and in both wings of *Bittacus* some slight modifications occur, i.e. in the hind wing of the three genera  $cu_1$ . is coalesced for a short distance with *m.*, and  $cu_2$ . with  $an_1$ ., and in the fore wing of *Bittacus*  $cu_1$ . is coalesced for a short distance with *m.* (See Pl. XXXIII., fig. 1; hind wings of figs. 2, 3, 4; more especially fig. 5.) In the hind wing of *Panorpa* and *Bittacus*, there is no or only one cross vein between *c.* and *sc.*, and  $an_1$ . and  $an_2$ . are connected by a cross vein on their independent portion, while in *Panorpodes* there are usually two cross veins between *c.* and *sc.*, and  $an_2$ . is connected by a vein with  $an_1$ . on its coalesced portion with  $cu_2$ . This fact seems to me to have been hitherto undescribed.

Recently ENDERLEIN, of Germany, has proposed many new genera in Mecoptera, chiefly based upon the arrangement of the veins. Thus two new genera, *Aulops* and *Campodotecnium*, were added to the Japanese fauna. However, after close examination of the veins in many specimens I find that the venation, the chief criterion of ENDERLEIN's genera, is subject to much variation and, in certain cases, quite unfitted for the settlement of generic characters. Let us quote the characters, relating to the veins, of *Panorpa*, *Aulops* and *Campodotecnium* as given by ENDERLEIN:—



*Panorpa*—"Clavus gross und lang. Subcosta erreicht im Vorderflügel das pterostigma, im Hinterflügel nur etwa die Mitte des Vorderrandes; in letzterem wird das Pterostigma durch eine Gabelader von  $r_1$  geschlossen. Im Vorder- und Hinterflügel: Radialramus mit langer Gabel, der vordere Arm meist 4 ästig (seltener 3 ästig).... Zwischen  $an$  and  $ax_1^*$  im Vorderflügel 2, im Hinterflügel 1 Querader.... Zwischen  $ax_1$  and  $ax_2^*$  im Vorderflügel 2, im Hinterflügel 1 Querader...."

*Aulops*—"Diese Gattung unterscheidet sich von *Panorpa* durch folgendes:

Die Subcosta mündet wie im Hinterflügel etwa in die Mitte des Flügelvorderrandes in die Costa und erreicht so das Pterostigma nicht, das ebenfalls wie im Hinterflügel durch eine Gabelader von  $r_1$  geschlossen wird.

..... Vorderer Radialgabelast meist 3 ästig (selten 4 ästig)."

*Campodotecnium*—"Unterscheidet sich von *Panorpa* durch folgendes.....

Clavus klein und kurz. Zwischen  $an$  und  $ax_1^*$  im Vorder- und Hinterflügel nur 1 Querader. Zwischen  $ax_1$  und  $ax_2^*$  im Vorderflügel eine, im Hinterflügel keine Querader....."

These facts we can analyze into the following elements:—

1. Peculiarity of the subcostal vein (in *Aulops*).
2. Number of branchlets of the first branch of  $rs$ .
3. Size of the clavus.
4. Number of cross veins connecting  $an_1$ — $an_2$ , ( $an$ — $ax_1$ ) and  $an_2$ — $an_3$ , ( $ax_1$ — $ax_2$ ) in both wings.

These are examined in detail under their respective headings.

### 1. PECULIARITY OF THE SUBCOSTAL VEIN.

The peculiarity of the subcosta—extending in the fore wing† scarcely beyond the middle of the costal margin—that constitutes the main character of the genus *Aulops* of ENDERLEIN, was already observed by M<sup>r</sup> LACHLAN.‡ Indeed most of our species bear this characteristic, of which he adds "a peculiarity only to be found in one true European species (*Panorpa alpina*), which otherwise has no intimate connection with the

\*  $ax_1$  and  $ax_2$  are equal to  $an_2$  and  $an_3$  in my paper.

† I do not speak of the hind wing, because it is almost alike in *Panorpa* and *Aulops* groups.

‡ M<sup>r</sup> LACHLAN: Trans. Ent. Soc. Lond., 1875, p. 183.



Japanese group." In Japan there exist together with this form certain species such as *Panorpa cornigera*, *gokaensis*, *golloisi*, *arakavae*, etc., which have the character of the European type. I have therefore studied the subcosta of both groups, and fortunately could discover the fact that the above stated two characters gradually pass one into the other and are never fixed. The following is a detail.

a. Modification of the subcosta.

My study of the wing-markings of *Panorpa*, the results of which are detailed farther on, having led me to the conclusion, that the markings of *Panorpa cornigera* and *Aulops*\* *pryeri* are so closely related that the one can be derived from the other, I proceeded to examine whether the resemblance was limited to the wing-markings only, or whether it extended to the generic characters, i.e. peculiarities of the subcostal veins.

In the normal form of *Panorpa cornigera*, as in other members of the group (or genus, according to ENDERLEIN), the subcosta *sc—p* (Pl. XXXIV., fig. 1) of the fore wing ends at the pterostigma, running almost parallel with the costa *c—p*, and there is a short transverse veinlet *t* between the two veins at about  $1/5$  of the length of the subcosta from its end. Now the subcosta shows certain modifications at this cross vein *t*. In some specimens (fig. 2), the cross vein *t* shortens into a mere spot, so that the subcosta comes into contact with the costa at that point (notice that in fig. 1 the right wing is drawn and in fig. 2 the left one). In this case the subcosta is divided into two portions *p—t* and *t—sc*. Again in some specimens further modifications occur in the outer portion *p—t*: in two specimens (a male and a female) the portion *p—t* swerves posteriorly so as partly to fuse together with the radius 1 (*r<sub>1</sub>*). This occurred in the female specimen similarly in both wings, but only in the right wing in the male specimen. This latter case is reproduced in Pl. XXXIV., fig. 3, in which the portion *p—t* is fused together with the radius along *c—d*. In such cases, the outer portion of the subcosta *p—t* is naturally divided into three parts: (1) *t—c* (2) *c—d* (coincident part) (3) *d—p*. In another female specimen (Pl. XXXIV., fig. 4), in the right wing, the outermost part *d—p* has entirely disappeared, so

\* In order to facilitate the explanation I use here Enderlein's genus *Aulops*; though, as is explained later, it does not possess a generic value.

that the subcosta (*sc.*) appears to end at *t*, becoming much shorter than in the typical form. In this specimen there is another short cross vein *t* in the region under consideration, which probably arose by accident and has no special meaning. These peculiarities are found in the right wing, the left having an almost similar subcosta with the specimen mentioned last. There is another female specimen (Pl. XXXIV., fig. 5), in the left wing of which the divided parts *t—c* and *d—p* have become very obscure (indicated with dotted lines in the figure), so that the normally developed part of the subcosta ends exactly at *t*, but bluntly in such a way as to remind us of the former (or potential) presence of the cross vein *t*, moreover, a small basal portion of the atrophied veins *t—c* is normally developed. Attention may also be called to the fact that the part *t—c* has a short branchlet at *b*. As the course of the branchlet *b* agrees with that of the ordinary subcosta, we may conclude that the modified subcosta *t—c* has a tendency to develop into the ordinary subcosta. Next, in the left wing of a male specimen (Pl. XXXIV., fig 6) the same modification occurs, and the divided parts of the subcosta *t—c* and *d—p* are also obscure. But in this specimen the subcosta *sc.* ends at *t* very acutely and not bluntly as in the last specimen, so that we can no longer infer the presence of the cross vein *t*. Finally, there is a female specimen captured on Mt. Gozu, Echigo, on June 9, 1910, by Mr. HATAKEYAMA, which shows an almost similar venation to that of the *Aulops* group (Pl. XXXIV., figs. 7, 8 and also text-figure 5, a). As can be seen from the figures, the subcosta (*sc.*) in this specimen terminates acutely in both wings as in the ordinary *Aulops* species. The false vein *t—c*, one of the two portions of the divided subcosta, is also present in this specimen. They are, however, not alike in both wings: in the right it is as in the preceding specimens, but in the left it arises not at *t* but at another point *t'* somewhat removed from *t*, so that there is an independent cross vein *t'—c* between the costa and subcosta. The other portion of the subcosta, *d—p*, is entirely absent in this specimen; but the radius 1 is forked and encloses pterostigma (Pl. XXXIV., figs. 7, 8, *ptr.*). In fact, so far as I know, the radius 1 is always simple (speaking of the fore wing) in the *Panorpa* group, while in the *Aulops* group it is forked, just as in the present example. Therefore, this specimen has, in this respect, an almost

similar venation to that of the *Aulops* group. The only difference is the presence, in the specimen, of the false veins  $t-c$  and  $t'-c$ ; but these are rather indistinct. One question remains, whether the disappearance of  $d-p$  in this specimen is due to extinction or to modification, so as to form the upper branch  $r_1-r_a$  of the radius 1 ( $r_1$ ); in the latter case  $d-p$  would be equal to  $r_1-r_a$ . This point can only be settled by a study of the development of the veins.



a



b

Text-figure 5.—a, a female specimen of *Panorpa cornigera*, which has the venation very closely allied to the *Aulops* type, captured by Mr. Hatakeyama. b, a male specimen of do., which has the venation of the *Aulops* type, sent me by Mr. NAKAHARA.  $\times$  about 4.

Quite recently I received another male specimen from Mr. NAKAHARA, captured in Harima on May 23, 1910. The specimen bears exactly the same venation as in the typical *Aulops*, and of course no trace is left that may remind us of the ordinary *Panorpa* type of venation that the insect originally should possess (text-figure 5, b).

From the above facts we can infer that the subcosta of *cornigera* may



undergo the following modifications: 1. The subcosta becomes joined to the costa by a shortening of the cross vein  $t$ ; 2. the outer portion  $t-p$  of the divided subcosta then swerves posteriorly, and uniting partly with the radius 1, tends to be divided into three parts:  $t-c$ ,  $c-d$ ,  $d-p$ ; 3. these three parts may partly or entirely disappear; 4. radius 1 becomes forked.

In this way the *Panorpa* type of venation of *Panorpa cornigera* is transformed into that of the *Aulops* type.

On the other hand I have examined many specimens of *Panorpa* (*Aulops*) *pryeri* of the *Aulops* group for similar examples, but unfortunately have found none.

As in the transformation above described the blunt ending of the subcosta at the costa becomes changed into the acute, I directed my attention to this point in many other species. In fact the termination is very variable in many *Aulops* species: as is figured in Pl. XXXIV., figs. 9a, 9b, it is sometimes blunt and sometimes acute, reminding us somewhat of the transitional stages above described, where the presence of the cross vein  $t$  caused the bluntness of the termination. The blunt ending is comparatively common in *lewisi* and rare in *klugi*. Figures 9a and 9b refer both to *lewisi*.

If the conclusion above stated be true, we can extend it further and say that the short subcosta of the *Aulops* group was formed from the long subcosta of the *Panorpa* group by the disappearance of the portion lying distally to the cross vein  $t$  in the latter.

b. Relative lengths of the subcosta to the wing in the *Aulops* group, and of the subcosta from the base to the cross vein  $t$  to the wing in the *Panorpa* group.

From the above stated facts we have learned that the subcosta of the *Aulops* group corresponds to that of the *Panorpa* group from the base to the cross vein  $t$ . And as these lengths are not fixed even in individuals of the same species it cannot be without interest to observe the variations of these lengths in both *Aulops* and *Panorpa* groups, and further to compare the modes of variation in the two groups. Thus I measured in the *Panorpa* group the length of the subcosta from the origin to the cross vein  $t$  and the length from  $t$  to the apex of the wing, and in the *Aulops* group the length of the subcosta from the origin to the end, and from the end to the



apex of the wing. To facilitate reference I shall call, in both groups, the former length, length I, and the latter length, length II. They are tabulated below :—

<i>Panorpa</i> group :				♀.	8. mm.	7. mm.	1. mm.
1. <i>cornigera</i> .				♂.	8. "	7.5 "	0.5 "
Sex.	Length I.	Length II.	Difference.	♀.	8. "	7.8 "	0.2 "
♀.	7.6 mm.	8. mm.	—0.4mm.*	♀.	8.1 "	8.9 "	—0.8 "
♂.	7.7 "	7.6 "	0.1 "	♂.	8.2 "	8.8 "	—0.6 "
♂.	7.7 "	8. "	—0.3 "	♀.	8.3 "	8.3 "	
♂.	7.8 "	6.9 "	0.9 "	♀.	8.4 "	8.1 "	0.3 "
♀.	7.8 "	8. "	—0.2 "	♀.	8.4 "	8.4 "	
♀.	7.7 "	6.9 "	0.8 "	♂.	8.5 "	7.8 "	0.7 "
♀.	7.7 "	7.5 "	0.2 "	♂.	8.5 "	7.8 "	0.7 "
♀.	7.7 "	7.5 "	0.2 "	♂.	8.5 "	8.1 "	0.4 "
♀.	8. "	8. "		♂.	8.5 "	8.3 "	0.2 "
♀.	8.4 "	7.4 "	1. "	♂.	8.5 "	8.3 "	0.2 "
♂.	8.6 "	7. "	1.6 "	♀.	8.5 "	8.7 "	—0.2 "
♀.	8.6 "	7.3 "	1.3 "	♀.	8.5 "	8.8 "	—0.3 "
♀.	9. "	7.9 "	1.1 "	♂.	8.6 "	7.6 "	1. "
2. <i>communis</i> .				♀.	8.6 "	8.3 "	0.3 "
♀.	6.4 "	5.3 "	1.1 "	♀.	8.6 "	8.8 "	—0.2 "
♂.	8. "	6.9 "	1.1 "	♂.	8.7 "	8.5 "	0.2 "
♀.	8.5 "	7.4 "	1.1 "	♀.	8.8 "	7.4 "	1.4 "
3. <i>golcaensis</i> .				♂.	8.9 "	8. "	0.9 "
♂.	7.6 "	7.2 "	0.4 "	♂.	9. "	7.3 "	1.7 "
♀.	7.9 "	7.6 "	0.3 "	♂.	9. "	7.9 "	1.1 "
4. <i>galloisi</i> .				♀.	9. "	8.3 "	0.7 "
♂.	7.1 "	7.2 "	—0.1 "	♂.	9. "	8.3 "	0.7 "
5. <i>arakavae</i> .				♂.	9. "	8.5 "	0.5 "
♂.	7.2 "	6.9 "	0.3 "	♂.	9. "	8.5 "	0.5 "
<i>Aulops</i> group :				♂.	9. "	8.6 "	0.4 "
6. <i>japonica</i> .				♂.	9. "	8.9 "	0.1 "
♀.	7.2 mm.	7.3 mm.	—0.1 mm.	♀.	9.2 "	8. "	1.2 "
♂.	7.2 "	7.7 "	—0.5 "	♀.	9.2 "	8.2 "	1. "
♀.	7.5 "	7. "	0.5 "	♂.	9.2 "	8.4 "	0.8 "
♀.	7.5 "	7.8 "	—0.3 "	♀.	9.3 "	8.5 "	0.8 "
♀.	7.5 "	8. "	—0.5 "	♀.	9.4 "	8.8 "	0.6 "
♀.	7.5 "	9.3 "	—1.8 "	♀.	9.4 "	8.8 "	0.6 "
♀.	7.8 "	8. "	—0.2 "	♀.	9.5 "	8.5 "	1. "
♀.	7.9 "	7.4 "	0.5 "	♀.	9.5 "	8.5 "	1. "
♂.	7.9 "	8. "	—0.1 "	♂.	9.6 "	8.1 "	1.5 "
				♂.	9.6 "	8.3 "	1.3 "
				♂.	9.6 "	8.9 "	0.7 "
				♀.	9.7 "	8.6 "	1.1 "
				♀.	10. "	8.3 "	1.7 "
				♀.	10. "	9.2 "	0.8 "

\* [—] sign indicates that length II is greater than length I.

Sex.	Length I.	Length II.	Difference.	♂.	8.5 mm.	6.8 mm.	1.7 mm.
♂.	10.1 mm.	9.1 mm.	1. mm.	♂.	8.5 "	7.2 "	1.3 "
♀.	10.1 "	9.9 "	0.2 "	♂.	8.5 "	7.6 "	0.9 "
♂.	10.4 "	8.9 "	1.5 "	♂.	8.5 "	8.2 "	0.3 "
♀.	10.4 "	9.5 "	0.9 "	♂.	8.5 "	8.2 "	0.3 "
♀.	10.4 "	10.2 "	0.2 "	♂.	8.9 "	7.2 "	1.7 "
♀.	10.9 "	9.2 "	1.7 "	♂.	9. "	7.7 "	1.3 "
♂.	11.2 "	9.6 "	1.6 "	♀.	9. "	7.9 "	1.1 "
7. <i>pulchra</i> .				♀.	9. "	7.9 "	1.1 "
♀.	7.6 "	7.6 "		♂.	9. "	8.1 "	0.9 "
♀.	7.7 "	7.7 "		♀.	9. "	8.2 "	0.8 "
♂.	7.8 "	7.2 "	0.6 "	♂.	9.1 "	7.5 "	1.6 "
♀.	7.8 "	8. "	-0.2 "	♂.	9.2 "	8.6 "	0.6 "
♀.	8. "	7.5 "	0.5 "	♀.	9.3 "	8.2 "	1.1 "
♀.	8. "	8. "		♂.	9.4 "	7.5 "	1.9 "
♀.	8.5 "	7.4 "	1.1 "	♀.	9.6 "	8.2 "	1.4 "
♂.	9.2 "	7.7 "	1.5 "	♂.	9.6 "	8.3 "	1.3 "
♂.	9.2 "	7.7 "	1.5 "	♂.	9.6 "	8.4 "	1.2 "
♂.	9.5 "	7.7 "	1.8 "	♀.	9.9 "	8.6 "	1.3 "
♀.	9.5 "	8.4 "	1.1 "	♀.	10. "	8.6 "	1.4 "
8. <i>rectifasciata</i> .				♀.	10. "	8.8 "	1.2 "
♂.	7.9 "	8.3 "	-0.4 "	♂.	10.2 "	7.5 "	2.7 "
♂.	8. "	7.2 "	0.8 "	♀.	10.2 "	8.8 "	1.4 "
♂.	8. "	7.6 "	0.4 "	♀.	10.3 "	8.3 "	2. "
♀.	8. "	7.8 "	0.2 "	12. <i>wormaldi</i> .			
♂.	8.3 "	8.5 "	-0.2 "	♂.	6. "	6.5 "	-0.5 "
♀.	8.4 "	8.7 "	-0.3 "	♂.	7.1 "	6.8 "	0.3 "
♀.	8.6 "	8. "	0.6 "	♀.	7.5 "	7.3 "	0.2 "
♂.	8.6 "	8.3 "	0.3 "	13. <i>leucoptera</i> .			
♂.	8.7 "	7.7 "	1. "	♂.	6.9 "	6.5 "	0.4 "
♀.	8.7 "	8.0 "	0.7 "	♀.	7.4 "	7.5 "	-0.1 "
♂.	9. "	7.8 "	1.2 "	♀.	7.4 "	7.5 "	-0.1 "
♂.	9.2 "	8. "	1.2 "	♀.	7.7 "	6.5 "	1.2 "
♀.	9.2 "	9. "	0.2 "	14. <i>striata</i> .			
♂.	9.5 "	8.5 "	1. "	♂.	7.8 "	6.9 "	0.9 "
♀.	9.9 "	10. "	-0.1 "	15. <i>multifasciaria</i> .			
♂.	11. "	8.7 "	2.3 "	♂.	6.5 "	6.5 "	
♀.	12. "	10.2 "	2.3 "	♀.	7.3 "	7. "	0.3 "
9. <i>bicornuta</i> .				♀.	8. "	7.9 "	0.1 "
♀.	7.4 "	7.1 "	0.3 "	♀.	8.2 "	7.2 "	1. "
♂.	7.6 "	6.7 "	0.9 "	16. <i>tacenouchii</i> .			
♂.	8. "	7. "	1. "	♀.	8. "	7.2 "	0.8 "
10. <i>halcusanensis</i> .				♂.	8.4 "	6.5 "	1.9 "
♀.	8.0 "	6.9 "	1.1 "	♀.	8.8 "	8.1 "	0.7 "
11. <i>pryeri</i> .				♀.	9. "	8. "	1. "
♀.	8.4 "	7.7 "	0.7 "	♀.	9.5 "	8.5 "	1. "

17. *nilkoensis*.

Sex.	Length I.	Length II.	Difference.
♀.	8.1 mm.	7.8 mm.	0.3 mm.
♀.	8.5 "	8. "	0.5 "

18. *klugi*.

♀.	6.5 "	6. "	0.5 "
♀.	6.5 "	6. "	0.5 "
♀.	6.5 "	7. "	-0.5 "
♀.	6.7 "	6.8 "	-0.1 "
♂.	6.9 "	6.6 "	0.3 "
♀.	6.9 "	7.4 "	-0.5 "
♀.	7. "	5.8 "	1.2 "
♂.	7. "	6.9 "	0.1 "
♀.	7. "	7.1 "	-0.1 "
♀.	7.1 "	6.9 "	0.2 "
♀.	7.2 "	6.9 "	0.3 "
♂.	7.2 "	7.5 "	-0.3 "
♀.	7.3 "	7.1 "	0.2 "
♀.	7.3 "	7.1 "	0.2 "
♀.	7.4 "	7.4 "	
♂.	7.4 "	7.6 "	-0.2 "
♀.	7.5 "	6.6 "	0.9 "
♀.	7.5 "	6.8 "	0.7 "
♀.	7.5 "	7. "	0.5 "
♀.	7.5 "	7.1 "	0.4 "
♀.	7.5 "	7.2 "	0.3 "
♀.	7.5 "	7.4 "	0.1 "
♀.	7.5 "	7.6 "	-0.1 "
♀.	7.6 "	6.7 "	0.9 "
♀.	7.6 "	7.4 "	0.2 "
♀.	7.6 "	7.5 "	0.1 "
♀.	7.7 "	7.5 "	0.2 "
♂.	7.8 "	7. "	0.8 "
♀.	7.8 "	7.3 "	0.5 "
♀.	7.9 "	6.6 "	1.3 "
♀.	7.9 "	6.8 "	1.1 "
♀.	7.9 "	7.2 "	0.7 "
♀.	8. "	6.5 "	1.5 "
♂.	8. "	6.8 "	1.2 "
♀.	8. "	7. "	1. "
♀.	8. "	7. "	1. "
♀.	8. "	7. "	1. "
♂.	8. "	7.1 "	0.9 "
♂.	8. "	7.1 "	0.9 "
♂.	8. "	7.2 "	0.8 "
♀.	8. "	7.2 "	0.8 "
♀.	8. "	7.2 "	0.8 "
♀.	8. "	7.4 "	0.6 "
♀.	8. "	7.6 "	0.4 "

♀.	8. mm.	8. mm.	mm.
♀.	8. "	7.8 "	0.2 "
♀.	8.1 "	7.5 "	0.6 "
♂.	8.1 "	7.7 "	0.4 "
♀.	8.1 "	7.9 "	0.2 "
♂.	8.2 "	6.6 "	1.4 "
♀.	8.2 "	6.9 "	1.3 "
♂.	8.2 "	8.2 "	
♀.	8.2 "	8.4 "	-0.2 "
♂.	8.2 "	8.5 "	-0.3 "
♂.	8.3 "	7.1 "	1.2 "
♂.	8.3 "	7.4 "	0.9 "
♀.	8.3 "	7.4 "	0.9 "
♀.	8.5 "	7. "	1.5 "
♂.	8.5 "	7.2 "	1.3 "
♂.	8.5 "	7.5 "	1. "
♀.	8.5 "	7.5 "	1. "
♀.	8.5 "	8. "	0.5 "
♂.	8.6 "	7. "	1.6 "
♀.	8.6 "	7.2 "	1.4 "
♀.	8.6 "	7.6 "	1. "
♀.	8.7 "	7.1 "	1.6 "
♂.	8.7 "	8.5 "	0.2 "
♀.	8.8 "	7. "	1.8 "
♀.	8.8 "	7.5 "	1.3 "
♂.	8.9 "	7.4 "	1.5 "
♂.	9. "	7. "	2. "
♀.	9. "	7.3 "	1.7 "

19. *trizonata*.

♂.	6. "	6.3 "	-0.3 "
♀.	7. "	6.8 "	0.2 "
♀.	7.5 "	6.5 "	1. "
♀.	7.5 "	7.1 "	0.4 "
♀.	7.5 "	7.5 "	
♀.	7.9 "	7. "	0.9 "
♀.	8. "	7. "	1. "
♀.	8. "	7.4 "	0.6 "
♀.	8.4 "	7.2 "	1.2 "
♂.	8.5 "	7.6 "	0.9 "
♂.	8.5 "	8. "	0.5 "
♂.	8.6 "	7.6 "	1. "
♀.	8.8 "	7.6 "	1.2 "
♂.	9.4 "	8. "	1.4 "

20. *ochracea*.

♂.	8. "	8.2 "	-0.2 "
♂.	9.5 "	7.5 "	2. "

21. *obscura*.

♂.	6.5 "	6.9 "	-0.4 "
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Sex.	Length I.	Length II.	Difference.	♀.	8.5 mm.	7.8 mm.	0.7 mm.
♀.	6.7 mm.	7. mm.	-0.3 mm.	♂.	8.5 "	8.3 "	0.2 "
♂.	6.9 "	6.6 "	0.3 "	♀.	8.6 "	8.1 "	0.5 "
♀.	7.2 "	6.9 "	0.3 "	♀.	8.6 "	8.2 "	0.4 "
♂.	7.5 "	8. "	-0.5 "	♂.	8.6 "	8.4 "	0.2 "
♀.	8.2 "	7.5 "	0.7 "	♀.	8.7 "	8.1 "	0.6 "
22. <i>ochraceopennis</i> .				♂.	8.9 "	9. "	-0.1 "
♀.	6.9 "	7.3 "	-0.4 "	♂.	9. "	8.1 "	0.9 "
♂.	7.5 "	7. "	0.5 "	♂.	9.2 "	8.2 "	1. "
♀.	7.5 "	7.2 "	0.3 "	♂.	9.3 "	8.1 "	1.2 "
♀.	7.5 "	7.2 "	0.3 "	♂.	9.6 "	8.2 "	1.4 "
♀.	7.6 "	7.2 "	0.4 "	♂.	9.7 "	8.5 "	1.7 "
♂.	8. "	6.5 "	1.5 "	♂.	10. "	8.5 "	1.5 "
♀.	8. "	7.6 "	0.4 "	♂.	10.4 "	8.2 "	2.2 "
♀.	8. "	7.8 "	0.2 "	23. <i>lewisi</i> .			
♂.	8.1 "	8. "	0.1 "	♂.	9.9 "	8. "	1.1 "
♀.	8.1 "	8.5 "	-0.4 "	♀.	10.3 "	9. "	1.3 "
♀.	8.2 "	7.5 "	0.7 "	♀.	10.5 "	8.2 "	2.3 "
♂.	8.2 "	7.8 "	0.4 "	♂.	10.5 "	8.5 "	2. "
♂.	8.2 "	8.6 "	-0.4 "	♂.	10.6 "	8.1 "	2.5 "
♂.	8.3 "	7.9 "	0.4 "	♂.	10.6 "	8.2 "	2.4 "
♀.	8.3 "	8.4 "	-0.1 "	♂.	11. "	8.4 "	2.6 "

We see from the above that in the relations of the two lengths, three cases are possible: 1. Length I greater than length II; 2. Both lengths equal; 3. Length I smaller than length II.

It is necessary to examine the relative proportion of these three cases in the groups *Panorpa* and *Aulops* as well as the several species. The result is tabulated below:—

<i>Panorpa</i> group.				
Name of species examined.	Total number of individuals examined.	Number of individuals in which length I > length II.	do., length I = length II.	do., length I < length II.
1. <i>cornigera</i> .	13	9	1	3
2. <i>communis</i> .	3	3		
3. <i>gokaensis</i> .	2	2		
4. <i>galloisi</i> .	1			1
5. <i>arakavae</i> .	1	1		
Total.	20	15	1	4



*Aulops* group.

Name of species examined.	Total number of individuals examined.	Number of individuals in which length I >length II.	do., length I = length II.	do., length I <length II.
6. <i>japonica</i> .	59	45	2	12
7. <i>pulchra</i> .	11	7	3	1
8. <i>rectifasciata</i> .	17	13		4
9. <i>bicornuta</i> .	3	3		
10. <i>hakusanensis</i> .	1	1		
11. <i>pyyeri</i> .	25	25		
12. <i>wormaldi</i> .	3	2		1
13. <i>leucoptera</i> .	4	2		2
14. <i>striata</i> .	1	1		
15. <i>multifasciaria</i> .	4	3	1	
16. <i>takenouchii</i> .	5	5		
17. <i>nikkoensis</i> .	2	2		
18. <i>klugi</i> .	72	60	3	9
19. <i>trizonata</i> .	14	12	1	1
20. <i>ochracea</i> .	2	1		1
21. <i>obscura</i> .	6	3		3
22. <i>ochraceopennis</i> .	29	24		5
23. <i>lewisi</i> .	7	7		
Total.	265	216	10	39
Total in both groups.	285	231	11	43

We thus see in our scorpion-flies that the first case, viz. length I being greater than length II, occurs most frequently, while the second and third cases are comparatively few, 231 out of 285 specimens belonging to the first, and 11 to the second, and 43 to the third case. We can therefore say that in our species length I is usually greater than length II; and this statement holds both for the *Panorpa* and the *Aulops* groups, as the ratio of the three cases is in the former 15 : 1 : 4 and in the latter 216 : 10 : 39.

Besides we see in the table of pages 299-302, that some examples of both groups incidentally represent the same numerals for lengths I and II, as for example an individual of *cornigera* and of *japonica* show for the lengths the same numerals 7.8 and 8.

## 2. NUMBER OF BRANCHLETS OF THE FIRST BRANCH OF THE RADIAL SECTOR.

The number of branchlets of the first branch of the radial sector of the fore wing are said by ENDERLEIN to be in the *Aulops* group mostly three and rarely four, and in the *Panorpa* group mostly four and rarely three. However, according to my own observations, the ratio of individuals with three and four branchlets are not very different in the Japanese species of the two groups; in both groups the ratio of individuals with three branchlets is larger than the other. The facts investigated in our species are tabulated below:—

<i>Panorpa</i> group.							
Name of species examined.	Total number of individuals examined.	Number of individuals with two branches.	Number of individuals with three branches.	Percentage of do.*	Number of individuals with four branches.	Number of individuals with five branches.	Number of individuals with dissimilar branches in the right and left wings.
1. <i>cornigera</i> .	16		16	100			
2. <i>communis</i> .	3		1	33	2		
3. <i>gokaensis</i> .	2		2	100			
4. <i>arakavae</i> .	1		1	100			
Total.	22		20	Total 333 Average 83	2		

<i>Aulops</i> Group.							
5. <i>japonica</i> .	24		9	38	15		
6. <i>pulchra</i> .	6		3	50	1		2

\* Decimals over 0.5 are taken as units and the rest are cut off.

Name of species examined.	Total number of individuals examined.	Number of individuals with two branches.	Number of individuals with three branches.	Percentage of do.*	Number of individuals with four branches.	Number of individuals with five branches.	Number of individuals with dissimilar branches in the right and left wings.
7. <i>rectifasciata</i> .	11	1	5	45	3		2
8. <i>bicornuta</i> .	3		2	67	1		
9. <i>hakusanensis</i> .	1		1	100			
10. <i>pryeri</i> .	10		6	60	3		1
11. <i>leucoptera</i> .	9		8	89	1		
12. <i>wormaldi</i> .	4		4	100			
13. <i>striata</i> .	1		1	100			
14. <i>multifasciaria</i> .	5		4	80			1
15. <i>takenouchii</i> .	9		9	100			
16. <i>nikkoensis</i> .	1		1	100			
17. <i>klugi</i> .	56		18	32	34	2	2
18. <i>trizonata</i> .	18		17	94			1
19. <i>ochracea</i> .	2		2	100			
20. <i>obscura</i> .	3		1	33	2		
21. <i>ochraceopennis</i> .	23		18	78	1		4
22. <i>lewisi</i> .	5		2	40	2		1
Total.	191	1	111	Total 1306 Average 73	63	2	14

*Panorpodes.*

23. <i>paradoxa</i> .	15		14	93			1
24. <i>decorata</i> .	3		3	100			
Total.	18		17	Total 193 Average 97			1

As can be seen from the above table, in the *Panorpa* group those which have three branchlets are 20 out of 22 individuals of five species, and in the *Aulops* group 111 out of 191 individuals of 18 species. The average per-

\* Decimals over 0.5 are taken as units and the rest are cut off.

centage becomes in the *Panorpa* group 83% and in the *Aulops* group 73%. This fact shows that individuals that have three branchlets occur in both groups similarly in abundance, and not so in the *Panorpa* group only as ENDERLEIN says.

Besides, there are some individuals, though very few, that have two or five branchlets, and there occur also some aberrant forms (for example those which have in the right wing three and in the left four, or the reverse) fairly frequently, as we have in the table 14 of such forms out of 191 individuals. The mode of branching is also never fixed; the foremost branch of  $r_2$  may have forked branchlets with a stalk, or the second branch of  $r_2$  may have the branchlets, or occasionally  $r_2$  itself may have three branches of the same origin with a single stalk, or very rarely  $r_3$  is forked outwardly. These various modes of branching occur not only in different species but also in individuals of the same species. In *Panorpodes*, 17 out of 18 have three branches and the remaining one must be considered as an abnormality, because it has in the right wing the usual three branches and in the left wing two. So we can say *Panorpodes* has usually three branches. *Bittacus* has quite another mode of venation, which it is unnecessary to quote here, but all which I examined had two branches.

### 3. SIZE OF THE CLAVUS.

The size of the clavus, or the basal area of the wings restricted by  $an_1$ , is also one of the characters proposed by ENDERLEIN in distinguishing *Panorpa* and *Aulops* from *Campodotecnium*. However the size of the clavi in the former two genera appears to vary frequently. Nevertheless I could not ascertain whether the smallest form found in the two genera is quite so small as that of *Campodotecnium*.

Between the clavi of *Panorpa* and *Aulops* no actual difference is found, and ENDERLEIN did not remark on it.

### 4. NUMBER OF CROSS VEINS BETWEEN $an_1$ .

AND  $an_2$ , AND  $an_2$ , AND  $an_3$ .

As characteristic of *Panorpa* and *Aulops* ENDERLEIN says that in the fore wing there are two cross veins between  $an_1$  and  $an_2$ , and  $an_2$  and  $an_3$ , and



in the hind wing one in the same places. And as characteristic of *Campodotecnum*, he says that in the fore wing there is one cross vein between  $an_1$  and  $an_2$ , and  $an_2$  and  $an_3$ , and in the hind wing one between  $an_1$  and  $an_2$ , and none between  $an_2$  and  $an_3$ . However, I have met with a number of individuals in *Panorpa* and *Aulops* which do not possess ENDERLEIN'S character in the fore wings, but the character in the hind wings appears to be well defined. The results of my investigation (in the fore wing) of the Japanese species are tabulated below:—

*Panorpa* Group.

Name of species examined.	Total number of individuals examined.	Number of individuals with cross veins: $\frac{an_1-an_2 \dots 2}{an_2-an_3 \dots 2}$	Number of individuals with cross veins: $\frac{an_1-an_2 \dots 1}{an_2-an_3 \dots 2}$	Percentage of do.	Number of aberrant forms.
1. <i>cornigera</i>	16	16		0	
2. <i>communis</i> .	3	3		0	
3. <i>gokaensis</i> .	2	1		0	1
4. <i>arakavae</i> .	1	1		0	
Total.	22	21			1

*Aulops* Group.

5. <i>japonica</i> .	15	4	7	47	4
6. <i>pulchra</i> .	7	1	3	43	3
7. <i>rectifasciata</i> .	12	4	6	50	2
8. <i>bicornuta</i> .	3	3		0	
9. <i>hakusanensis</i> .	1	1		0	
10. <i>pryeri</i> .	12	8		0	4
11. <i>leucoptera</i> .	9	7		0	2
12. <i>wormaldi</i> .	4	4		0	
13. <i>striata</i> .	1		1	100	
14. <i>multifasciaria</i> .	5	4		0	1

Name of species examined.	Total number of individuals examined.	Number of individuals with cross veins: $an_1$ — $an_2$ .....2 $an_2$ — $an_3$ .....2	Number of individuals with cross veins: $an_1$ — $an_2$ .....1 $an_2$ — $an_3$ .....2	Percentage of do.	Number of aberrant forms.
15. <i>takenouchii</i> .	8	8		0	
16. <i>nikkoensis</i> .	1	1		0	
17. <i>klugi</i> .	63	19	34	54	10
18. <i>trizonata</i> .	15	15		0	
19. <i>ochracea</i> .	2		1	50	1
20. <i>obscura</i> .	3		2	67	1
21. <i>ochraceopennis</i> .	19	18		0	1
22. <i>lewisi</i> .	4		2	50	2
Total.	184	97	56	$\frac{\text{Total 461}}{\text{Average 21}}$	31

*Panorpodes*.

23. <i>paradoxa</i> .	14		14	100	
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As can be seen from the table, out of 184 individuals of 18 *Aulops* species, there are 56 examples which bear one cross vein between  $an_1$  and  $an_2$ , though between  $an_2$  and  $an_3$  there are two cross veins. The average percentage of such examples amounts to 21%. This is of course very small, still it is too numerous to allow one to overlook it as anomalies of the ordinary forms. More than this—for example in *klugi*—such forms represent 54%, in *obscura* 67%, and in *trizonata* and *lewisi* 50% of all, so that in these species such forms should be considered as of normal occurrence. Further, 14 specimens of *Panorpodes* that I examined showed exclusively this form. Anomal forms frequently occur, as one may see by the table. Amongst them the following are commonly found:—

$$gokaensis. \quad \frac{2}{2} \cdot \frac{3}{2}.*$$

\* The upper and lower numerals indicate respectively number of cross veins between  $an_1$ — $an_2$  and  $an_2$ — $an_3$ ; the right and left figures show respectively the right and the left wing.

<i>japonica.</i>	$\frac{2}{2} \cdot \frac{1}{2}; \frac{2}{2} \cdot \frac{1}{1}; \frac{1}{2} \cdot \frac{2}{2}; \frac{1}{3} \cdot \frac{1}{2}; \frac{1}{2} \cdot \frac{1}{1}; \frac{1}{0} \cdot \frac{1}{2}.$
<i>bicornuta.</i>	$\frac{2}{2} \cdot \frac{5}{2}; \frac{2}{2} \cdot \frac{1}{2}; \frac{2}{2} \cdot \frac{3}{2}.$
<i>pryeri.</i>	$\frac{2}{2} \cdot \frac{1}{2}; \frac{1}{2} \cdot \frac{2}{2}.$
<i>multifasciaria.</i>	$\frac{1}{2} \cdot \frac{2}{2}.$
<i>klugi.</i>	$\frac{0}{1} \cdot \frac{1}{1}; \frac{1}{1} \cdot \frac{1}{1}; \frac{1}{2} \cdot \frac{2}{2}; \frac{1}{1} \cdot \frac{1}{2}.$
<i>ochraceopennis.</i>	$\frac{2}{2} \cdot \frac{3}{3}.$
<i>levisi.</i>	$\frac{1}{3} \cdot \frac{1}{1}; \frac{1}{1} \cdot \frac{2}{2}.$
<i>rectifasciata.</i>	$\frac{1}{2} \cdot \frac{1}{1}; \frac{2}{1} \cdot \frac{1}{2}.$

In the hind wing, all the specimens of *Aulops* and *Panorpa* in the collection before me possess the typical number of cross veins proposed by ENDERLEIN, i. e. one in  $an_1$ .— $an_2$ . and another in  $an_2$ .— $an_3$ ., but the length and position of the cross vein between  $an_2$ .— $an_3$ ., is highly variable. In certain examples it is situated very close to the origin of  $an_2$ . and  $an_3$ ., therefore it is extremely short, and in some it is situated outwardly near the posterior margin, therefore it is very long. Let the cross vein in the former case traverse to the origin of veins so that it will disappear and the type form of *Campodotectum* will appear. Though I have not yet met with such specimens, the difference of this and the above stated example with the short cross vein appears to me actually very small.

The statement of ENDERLEIN in his recent paper on the Mecoptera of Java, that my *ochracea*, *brachypennis*, *rectifasciata* and *trizonata*, and *nipponensis* of NAVAS belong to the genus *Campodotectum*, may be wrong, because these species bear more characters of *Aulops* than of *Campodotectum*.

##### 5. CONCLUSION.

From the above stated facts we can conclude that the characters proposed by ENDERLEIN for separating *Aulops* from *Panorpa* are, so far as vena-

tion is concerned, of a variable character, and are not sufficient to be regarded as of generic value. These characters being in fact the principal thing of all that he proposes, the other subordinate characters must be considered as of less value. Even these, as is explained in another place, are still more uncertain than the principal characters. For this reason I am of the opinion that the two genera *Panorpa* and *Aulops* of his should be considered at most as only subgenera.

At the same time the characters he uses to distinguish *Panorpa* and *Aulops* from *Campodotecnium* are of a highly variable nature, so far as the venation is concerned, except the difference in size of the clavi and the character represented in the hind wing, i. e. the occurrence or absence of the one cross vein between  $an_2$ — $an_3$ . Other characters besides the venation proposed by ENDERLEIN are equally inadequate for generic distinction, since they are never limited to any particular genus. If this be the case, the characters of *Campodotecnium* are too slight to allow one to recognize it as a genus, and it seems to be more natural to look upon it at most also as a subgenus. However as there are some characters peculiar to *Campodotecnium* I do not intend to sink the genus. I only consider them insufficient.

## VI. The Wing-Markings.

Under this heading I discuss the wing-markings of *Panorpa* chiefly, because they are highly developed and complicated in that genus. A few species of *Panorpodes* have also some wing-markings, the study of which is appended to the end of the chapter. The wing-markings of *Panorpa* may be broadly classified under the following headings: 1. pterostigmatal fascia, 2. apical dark area, 3. supplementary markings. In the following lines, first these parts are studied respectively and finally a phylogenetic conclusion is formed on the whole. The ground colour of the wings and hues of the wing-markings may differ in species as well as in individuals of the same species so that they also require to be studied.

Broadly speaking, the markings of Panorpidæ (frequently the ground colour of wings as well) are usually more distinctly or more fully developed in the fore wing than in the hind one. This may possibly be due to the



fact that the hind wing is usually covered by the fore wing when the insect is in repose. For this reason I have chiefly studied the markings of the fore wing.

### 1. PTEROSTIGMATAL FASCIA.

The pterostigmatal fascia is undoubtedly the most conspicuous part of the wing-markings of *Panorpa*; it commences anteriorly at the pterostigma, entirely or partly covering it—commonly the inner half or inner one-third or sometimes a very small portion is covered—and reaches to the posterior margin. It plays an important part in taxonomy, so far as wing-markings are concerned. We have to reduce all its divergent variations into a system, that is, intricate forms are to be traced to simple ones and simple ones to primitive ones, and finally we have to find out the original form of the fascia, whence all the divergent forms must have descended, and taking it as a starting point, to account for all the features represented in our Panorpids.

#### a. Origin and formation of the pterostigmatal fascia.

The pterostigmatal fascia is undeveloped in *galloisi*, *lewisi* and *nikkoensis*, and is in the form of a spot, and occasionally imperfect in *bicornuta*, *leucoptera* and *takenouchii*, being in the form of a spot or short stria. Of these undeveloped forms the simplest one is that of *galloisi*, in which the pterostigmatal fascia is represented by a small costal spot situated at the middle of the pterostigma (Pl. XXXIV., fig. 10). In *lewisi* it is likewise small, but is situated at the commencement of the pterostigma and is associated moreover with a large apical patch. In *nikkoensis* the spot is placed at the inner one-third of the pterostigma and is accompanied by two spots arranged internally along the subcosta and a very small apical spot; in this species there is another very small spot at the posterior margin, just at the position where the ordinary pterostigmatal fascia ends. In a certain form of *bicornuta* (Pl. XXXVI., fig. 2), the costal spot is conspicuously large and ends only in half the length of the ordinary fascia. In *cornigera* and *leucoptera* (Pl. XXXVI., fig. 17), the pterostigmatal fascia ends occasionally without reaching the posterior margin. In some exceptional cases the fascia assumes the form of a spot and ends before, or at the middle of the wing. *Takenouchii* has a very conspicuous and large pterostigmatal spot which occupies half the breadth

of the wing; in this species there are two large spots on the posterior margin opposite to the pterostigmatal spot. These three or the outer two spots often fuse into one in the form of a  $\Lambda$  or  $<$  (Pl. XXXVI., figs. 7, 10).

Of the examples mentioned above, the most primitive form is undoubtedly that of *galloisi*, in which the costal spot is smallest and simplest and is accompanied by no other markings. I select this form as the origin of the pterostigmatal fascia. Next come the aberrant forms of *cornigera* and *leucoptera*. Then perhaps comes *nikkoensis*. Though *levisi* has also the very primitive pterostigmatal spot, it has the well developed apical dark area just as in many other species. From these facts we may conclude that the pterostigmatal fascia originated as a small costal spot placed at the middle of the pterostigma. Afterwards one or two small spots arose extending obliquely and backwardly as can be seen in examples of *cornigera*, *nikkoensis* and *leucoptera*. Next these three spots became enlarged or elongated, so as to fuse together and form an imperfect fascia, which further developed into an ordinary fascia (*cornigera* and *leucoptera*).

b. Deviation of the starting point of the fascia from the pterostigma.

The pterostigmatal fascia in such species as *cornigera*, *gokaensis*, *pryeri*, *bicornuta*, *striata* and *multifasciaria* is more oblique than in other species and occupies the entire area of the pterostigma, while in other species the fascia arises at the internal end of it and is more direct. Transitional forms, however, can easily be traced in the above stated species, especially amongst individuals of *pryeri*, the common species in Japan. In some forms of this species, the pterostigmatal fascia arises typically from the pterostigma, occupying the entire area of it. In other examples it starts at the internal end of the pterostigma which, however, is entirely occupied by the remnant of the fascia, so that the fascia has the form of a  $\Gamma$ . Finally the upper right hand (the remnant of the fascia in the pterostigma) disappears, so that the fascia arises directly at the internal end of the pterostigma, the outer portion of the latter being entirely free from the fascia. This is the ordinary form of the pterostigmatal fascia found in most species of our *Panorpa*.

c. Widening.

The pterostigmatal fascia is rather narrow in *cornigera*, *leucoptera*, *pryeri*, *wormaldi*, *multifasciaria*, *striata*, etc. but rather broad in *japonica*, *rectifasciata*,

*trizonata*, *ochraceopennis* and certain forms of *klugi* etc., and of intermediate width in *golcaensis*, *bicornuta*, *klugi*, *obscura*, etc. In *klugi* the pterostigmatal fascia is highly variable, narrow, broad and intermediate forms all being present. Whilst the median forms graduate into the broad forms, there is a distinct gap between them and the broadest of the narrow forms.

d. Furecation on the outer edge.

The outer edge of the pterostigmatal fascia is not always even. In some species it is curved or angulated externally, or has a short projection or sinuation or furecation. The outer furecate portion is sometimes short and sometimes long, and in the latter case may reach to the posterior margin of the wing. The furecate portion is usually very slender and looks like a subordinate branchlet, but in some examples of *trizonata* it is rather broad and forms a large branch. In *striata*, *communis*, *multifasciaria* and *wormaldi*, the branch is as broad as the fascia itself, so that the entire fascia is dichotomously divided. Again, in some cases this furecate portion, separating from the main fascia and remaining on the posterior margin, constitutes a marginal spot. All these variational forms can be seen abundantly in a single species, *klugi* (see Pl. XXXVII., figs. 11-34); they are also not infrequent in *japonica*. The primitive form of the furecation may be found in the fascia of *pryeri*. In this species the furecate portion appears at first as a small projection. Commonly this state persists in this species. In a few specimens it is branched. In *klugi* all forms of furecation are exemplified; when the fascia is slender it looks like that of *pryeri*, and when broad it is quite similar to that of *japonica*. *Rectifasciata*, *obscura* and typical *klugi* have both edges of the fascia entire, while *ochraceopennis* has only the outer edge entire.

e. Unevenness of the inner edge.

Though the outer edge of the pterostigmatal fascia is changed in a thousand ways, the inner edge is usually in most species very sharply defined. Occasionally as in *japonica*, some spots are developed at or near the inner edge; in such cases it becomes uneven. *Ochraceopennis* is another exception to this rule, inasmuch as the inner edge is always furecate on two spots anteriorly and posteriorly, while the outer edge is usually clearly defined.



## 2. APICAL DARK AREA.

## a. Origin.

Most species of *Panorpa* have a dark area at the apex of the wing. In the most primitive form, like *galloisi*, it is wanting. In some examples of *cornigera* it is also wanting, but in some the apex of the wing is slightly tinged with black (Pl. XXXVI., fig. 5), and in others it is developed along the apical margin in the form of a crescent (Pl. XXXVI., fig. 6). In some forms this crescentic mark is slightly removed from the apical margin towards the base of the wing, so that there remains a hyaline margin. These narrow apical markings may possibly be the origin of the apical dark area. In *leucoptera*, *pryeri* and *arakavae* this apical crescentic mark is usually present\* and there occurs an indefinite short streak (Pl. XXXVI., figs. 8, 14, 16). Again in some examples of *leucoptera* and *pryeri* two or three, or sometimes more, irregular patches are found in the place of the streak (Pl. XXXVI., fig. 13). In *pryeri* subsp. *major* (Pl. XXXVI., fig. 12) these patches unite with one another, so as to form an incomplete, broad, apical dark area, enclosing certain hyaline patches within. In this way the typical dark area found in *klugi*, *japonica*, etc. may possibly be formed. The apical dark area of *communis* resembles the form just mentioned. In *wormaldi*, *multifasciaria*, *striata* and *hakusanensis* the apical dark area is formed in quite another way; in *wormaldi* and *multifasciaria* the apical portion bears three striae between the costal and posterior margins, one of which is furcate in the lower half; in *striata* and *hakusanensis* there are two striae, another one found in *wormaldi* and *multifasciaria* being reduced to a posterior marginal patch in *striata*, and entirely wanting in *hakusanensis*. These two or three striae correspond to the apical dark portion of other species.

In *nikkoensis* the apical crescent is modified into an elliptical mark placed at the very apex of the wing (Pl. XXXVI., fig. 4). In *gokaensis* and *bicornuta* this elliptical mark is strongly pronounced and shows a tendency to move anteriorly.† In *takenouchii* there is a rather anteriorly placed apical patch; it is sometimes elliptical and sometimes irregular, being formed by two con-

\* In some forms of *leucoptera* it is often obsolete.

† Sometimes absent in *bicornuta*.



joined spots. Besides, there is another supplementary spot in this species at the posterior margin, separate from the patch just mentioned. *Lewisii* has without exception a prominent apical elliptical mark placed slightly towards the anterior margin (Pl. XXXV., fig. 16). In *ochraceopennis* the apical mark has the form of a semi-circle and is placed slightly forward, more slightly, however, than in the preceding species. In *klugi*, *japonica*, *rectifasciata*, *trizonata* and others the apex is broadly tinged with black in the form of a semi-circle and usually not placed forward.

b. Changes in the inner edge.

The inner edge of the apical dark area is highly variable. In *klugi* it is sometimes even (Pl. XXXVII., fig. 13), sometimes sinuous (Pl. XXXV., fig. 14) and occasionally there is a small notch (Pl. XXX., fig. 13). In *japonica* the edge is usually slightly sinuous and in *rectifasciata* usually almost entire, though exceptions can occasionally be found. In *ochracea*, typical *klugi*, *obscura* and *trizonata*, the edge is slightly concave beyond the middle of the wing. The concavity is sometimes very prominent in the last species. In *lewisii* the edge is always straight and oblique. In *ochraceopennis*, differently from *klugi* and *japonica*, the notch usually occurs anteriorly before the middle of wing.

### 3. SUPPLEMENTARY MARKINGS.

Besides the markings above described, there are in some species supplementary markings in the area between the pterostigmatal fascia and the apical dark portion (the area external to the fascia) and in the area between the fascia and the base of the wing (the area internal to the fascia). They are generally developed much more distinctly in the fore than in the hind wing.

a. Markings in the area external to the pterostigmatal fascia.

The markings in this area can be considered partly as a portion of the apical dark area and partly as a furcate portion of the pterostigmatal fascia. Thus, as already explained, all the striae (except one) of the outer area of *cornigera* (in rare examples), *pygmaea*, *leucoptera*, *wormuldi*, *striata*, *arakavae*, *hakusanensis* and *multifasciaria* would be transformed into the ordinary apical dark portion, if we imagine them to enlarge and fuse together. Moreover,

this actually takes place in some specimens of *pryeri* subsp. *major* (Pl. XXXVI., fig. 12), so that an incomplete apical dark portion is formed. The single remaining stria at the posterior margin situated nearest to the pterostigmatal fascia may be considered as a furcate portion of the fascia, since by producing it forward we obtain a form of furcate fascia, which actually occurs occasionally in certain examples of these species. In the apical patches of *takenouchii* we see the relation still more clearly. A similar case is also found in *pryeri* subsp. *major* with pronounced markings. In some forms of *klugi* (Pl. XXXV., fig. 11), *japonica* (Pl. XXXV., fig. 1, 3) and many others, there is only a small marginal spot between the fascia and the apical dark portion. This is of course the remainder of the furcate branch of the pterostigmatal fascia, as its history can easily be traced in series of each species (see Pl. XXXV., figs. 1, 3, 5, 6 and Pl. XXXVII., figs. 29-34).

*b.* Markings in the area internal to the pterostigmatal fascia.

Though in certain forms of *cornigera*, *klugi* (subsp. *nipponensis*) and *ochraceopennis*, and in all forms of *rectifasciata*, *obscura* and *lewisi* there are no markings found in this area, other species commonly have one, two or more patches or striae in the area, and these patches are highly variable both according to species and to individuals. As these markings have usually no connection\* with the pterostigmatal fascia I am inclined to consider them to be of different origin rather than derivatives of the pterostigmatal fascia. In fact, in *gokaensis* and *trizonata* there is another complete fascia corresponding to these markings in the area internal to the pterostigmatal fascia.

These markings in the area can broadly be classified into three groups:—

1. Markings along the costa or radius; 2. markings along the posterior margin or media; 3. anteroposterior markings parallel to the pterostigmatal fascia. In some forms of *cornigera* and *nikkoensis* the markings of the first group only are present, i.e. a square patch between *sc.* and *r<sub>1</sub>*, and a triangular patch at the juncture of the radial sector. In *cornigera* this first patch is occasionally developed into a streak. In *pryeri* and in typical *leucoptera*, besides the well developed markings of the first group, those of the second are also partly developed, either in the form of a streak on the median vein

\* Very rarely in *ochraceopennis* and *japonica* are these markings connected with the pterostigmatal fascia.

or in the form of a patch at the posterior margin. In *wormaldi*, *striata* and *multifasciaria* the markings of the first and second groups are well developed; those of the first group are developed just as in *pryeri*, or more pronounced (in this case there is a rather broad streak along the stalk of the radius), and the second group includes, besides the markings of *pryeri*, another more internally placed patch, between which and the base of the wing a broad, rather irregular, marginal fascia is found. In *bicornuta* the markings of the first group only are developed in full; in this species the costal area including the stalk of the radius is tinged with black from the base to the end of the subcosta, the spot at the juncture of the radial sector being enclosed within. In *lakusanensis* those of the first group are developed just as in *bicornuta*, but it has moreover, markings of the second group rather allied to that of *pryeri*. *Ara-kawae* much resembles the former species but the markings are rather irregular and those of the first group are less developed. In *takenouchii* both those of the first and second groups are well developed in the form of three large patches at each margin.

Markings of the third group which run anteroposteriorly, may be found usually in *japonica* (Pl. XXXV., figs. 1, 2, 3, 5, 6), in which a somewhat quadrate spot occurs anteriorly between  $r_1$ . and  $r_2$ . and posteriorly between  $cu_1$ . and  $cu_2$ . Of the two spots the posterior one is usually larger than the anterior. In *klugi*, the anterior one is usually smaller than the posterior one, and often becomes obscure (Pl. XXXVII., figs. 29, 30, 31). In the subspec. *quadrifasciata* (Pl. XXXV., fig. 12; Pl. XXXVII., fig. 34) the posterior spot is much larger and of quadrate form, and is connected with the anterior one by a streak. In *pulchra* (Pl. XXXV., fig. 4) the two spots are always present, which unite with each other so as to form an irregular fascia, and another spot or series of two spots is placed still internally. I call this latter series "inner series" in contradistinction to the former "outer series." The anterior spot of the inner series usually happens to unite obliquely with the posterior one of the outer series, so that they represent an irregular form of V. Besides, a posterior marginal spot is occasionally present still more internally, which is sometimes very large and occupies the posterior half of the basal area (see Pl. XXXV., fig. 4.). In *communis* the outer series and the anterior spot of the inner series and another still more internally situated spot



are usually present, and often the posterior one of the outer series is conjoined with the anterior one of the inner series, so as to form an incomplete oblique fascia just like that of the last mentioned species. The occurrence of a complete internal fascia may be seen in *gokaensis* and *trizonata* (Pl. XXXV., figs, 17, 18; Pl. XXXVI., fig. 3). In the former species it is confined to the fore wing, and no other spots are present. In the latter species it occurs in both wings, and usually there is a costal spot between the internal and the pterostigmatal fascia (Pl. XXXV., fig. 17). This spot is also present in *pulchra*. Sometimes, however, the spot is obsolete in *trizonata* (Pl. XXXV fig. 18).

Finally there remains the question whether the irregularity of the inner margin of the pterostigmatal fascia in *ochraceopennis* is due to the coalescence of the above mentioned supplementary series of spots with the fascia, or whether the fascia itself has become rugged. This cannot be easily solved; but the latter assumption is in many cases very serviceable.

#### 4. THINNING OF THE COLOUR AND FENESTRATION OF THE MARKINGS.

Under the various circumstances in nature, great variability in the intensity of the colours of the wing-markings may occur among many species. Thus in *pryeri*, *leucoptera*, *klugi*, *japonica* and many others, the wing-markings are often paler but are occasionally blackish to piceous or piceous to testaceous. In *wormaldi*, however, they are always paler than in other species.

In the description of *macrogaster*, of which I have unfortunately not seen a specimen, M'LACHLAN says that the pterostigmatal fascia and the apical dark area are traversed longitudinally by a pale line between each of the veins, so that it appears fenestrate. Though I have not yet met with a specimen with completely fenestrate wing-markings, still I have some specimens of *japonica*, *pulchra* and *klugi*, in which the markings are fenestrate in the posterior half of the wings (see Pl. XXXV., figs. 4, 5, 6). I am therefore of the opinion that the fenestration of the wing-markings is not sufficient ground for regarding *macrogaster* as a distinct species, so long as other characters are not essentially different from those of *japonica*.



## 5. YELLOWISH TINGE OF WING.

Certain species of *Panorpa*, such as *klugi*, *lewisi*, *ochracea*, *ochraceopenis*, *obscura* and *trizonata*, are remarkable for the yellowish or testaceous tinge of their wings. Though this tinge is considered as one of the characters of these species, it sometimes disappears in them and occasionally appears in other species. Thus in some forms of *japonica*, *communis*, *rectifasciata*, *pryeri*, *leucoptera* and very rarely even in *cornigera*, the wings are tinged with a light yellowish colour, which is more strongly developed in the fore than in the hind wing. But as such cases are comparatively very few we may consider them as anomalies, and we can broadly classify our *Panorpa* by the tinge of wings.

The pterostigma is in most species opaque or more deeply tinged than the ground colour, and often is easily recognized at a glance, while in some forms of *klugi* it is not remarkably different from the ground colour.

## 6. PHYLOGENETIC CONCLUSION.

Looking over the wing-markings of our Panorpids, we are struck on the whole with the fact that they may be classified into two groups, viz. 1. The group in which the apical dark portion is incompletely developed, that is, represented by one or more patches or streaks, or often entirely absent, and the pterostigmatal fascia rather narrow;\* 2. The group in which the apical dark portion is completely developed and the pterostigmatal fascia rather broad.†

## Group 1.

<i>cornigera</i> ,	<i>communis</i> ,	<i>gokaensis</i> ,†	<i>galloisi</i> ,
<i>arakavae</i> ,	<i>sauteri</i> ,‡	<i>bicornuta</i> ,	<i>hakusanensis</i> ,
<i>pryeri</i> ,	<i>wormaldi</i> ,	<i>leucoptera</i> ,	<i>striata</i> ,
<i>multifasciaria</i> ,	<i>takenouchii</i> ,§	<i>nikkoensis</i> .	

\* In *gokaensis* the fascia is rather broad, as in *klugi*.

† In *lewisi* the fascia is entirely wanting.

‡ I have not yet seen the specimen; it is very difficult to judge its position from the description and the figure given by PETERSEN.

§ Some specimens bear the character of the second group.

## Group 2.

<i>formosana</i> ,*	<i>ophthalmica</i> ,*	<i>japonica</i> ,	<i>pulchra</i> ,
<i>rectifasciata</i> ,	<i>sachalinensis</i> ,*	<i>klugi</i> ,	<i>trizonata</i> ,
<i>ochracea</i> ,	<i>obscura</i> ,	<i>ochraceopennis</i> ,	<i>lewisi</i> .

Speaking generally, in the first group the wing-markings are variable in many ways, while in the second group the elements of the markings are fixed. And as in the first group many primitive wing-markings are found, we have reason to consider it to be more primitive than the second, which must have naturally arisen from the first.

Now in the first group, the species that has the simplest markings is undoubtedly *galloisi*, which may be considered as the original form of our *Panorpa*, as far as the wing-markings are concerned. Next probably comes *cornigera*, as certain forms of it have wing-markings as simple as those of *galloisi*. Next to this probably *pryeri*, as some forms of *cornigera* with pronounced wing-markings are very closely allied to *pryeri*, with less developed wing-markings. Here, however, lies a gap between the two species, i. e. the difference in the venation detected by M'LACHLAN. However, even this, as already explained, shows a gradual transition from *cornigera* to *pryeri* in accordance with the markings.

*Pryeri* itself is a very variable species, so that it is rather convenient to consider it as the central type of the first group. When its markings become obscure and interrupted, *leucoptera* would result. And if the interrupted markings of the latter become enlarged, certain forms, with less pronounced markings, of *takenouchii* (and probably *sauteri* as well) will be formed. And again if the interrupted wing-markings of *leucoptera* remain only at the anterior costal region, something closely resembling *nikkoensis* would be obtained.

On the other hand, the addition of many fine striae to the apical part of the wing-markings of *pryeri* would result in such forms as *striata*, *wormaldi* and *multifasciaria*. The phylogeny of most species of the first group is thus traceable. Of the remaining species *communis*, *gokacensis*, *arakavae*, *lukusanensis* and *bicornuta*, the first one cannot be directly connected with any species, though somewhat allied to *cornigera*. *Arakavae* can be formed by

\* Judged only from the description and figure.

adding some striae to *cornigera*. *Bicornuta* may be easily deduced from *cornigera*, by a suffusion of the costal half of the wing with black. A gap in venation occurs again between these species, but it can be easily filled in the same manner as in the case of *cornigera* and *pyleri* above mentioned. *Hakusanensis* can be formed by adding some striae to *bicornuta*. Finally *gokaensis* also can be formed from *cornigera* by the addition of an internal fascia in the fore wing.

The second group we can again divide into two sub-groups, according as wings are tinged or not.

Sub-group a. Wings with ochreous or testaceous tinge :

*ophthalmica*,                      *klugi*,                      *trizonata*,                      *ochracea*,  
*obscura*,                      *ochraceopennis*,                      *lewisi*.

Sub-group b. Wings colourless, or slightly coloured towards the base :

*japonica*,                      *rectifasciata*,                      *pulchra*.

In the second group I take *klugi* as the central type, because it is the most variable of all and many species can be derived from it, though the presence of ochreous tinge in the wing makes this slightly hazardous.\*

The pterostigmatal fascia of *klugi* has two tendencies, one to be sharply defined on both its edges, and the other to be furcate on the outer edge. If the former tendency obtained and the colouration be preserved, typical *klugi* and *ochracea* would result, and from the latter *obscura* can be derived. If the latter tendency obtained and the supplementary markings be strongly developed, so as to form an internal fascia, a form like *trizonata* would be produced. *Lewisi* and *ochraceopennis* are rather modified forms. However, we can connect *klugi* and *ochraceopennis* in certain ways, and if the pterostigmatal fascia should disappear in the latter species we should obtain *lewisi*. The form of *klugi* with furcate fascia would lead to *japonica*, if the tinge of the wing be lost. Again, if the furcation of the pterostigmatal fascia and accessory spots of *japonica* be lost, a form of *rectifasciata* would be produced. Let the markings of *japonica* be fenestrated, and we get a feature of subspec. *macrogaster*. If supplementary markings are developed in *japonica* forms of *pulchra* would result. Thus we see that in both coloured and hyaline groups markings develop in an almost similar way, since the supplementary markings happen

\* Occasionally in *klugi* the ochreous tinge disappears.



to develop so as to form the internal fascia in both groups, although in the hyaline group it is very irregular and not perfect as in the coloured group.

I cannot treat here of *ophthalmica*, *formosana* and *sachalinensis*, because I have not yet seen any specimen. However, their markings may in certain ways be formed from the *klugi* type.

The connection between the two groups above dealt with is rather difficult to trace. Though it is highly probable that group 2 originated from group 1, yet the direct connection of the two groups cannot be actually detected, as there is a small but distinct gap between them. Nevertheless *pygeri* of the first group and *klugi* of the second group can be connected in certain ways; but the result is not satisfactory and further study is necessary.

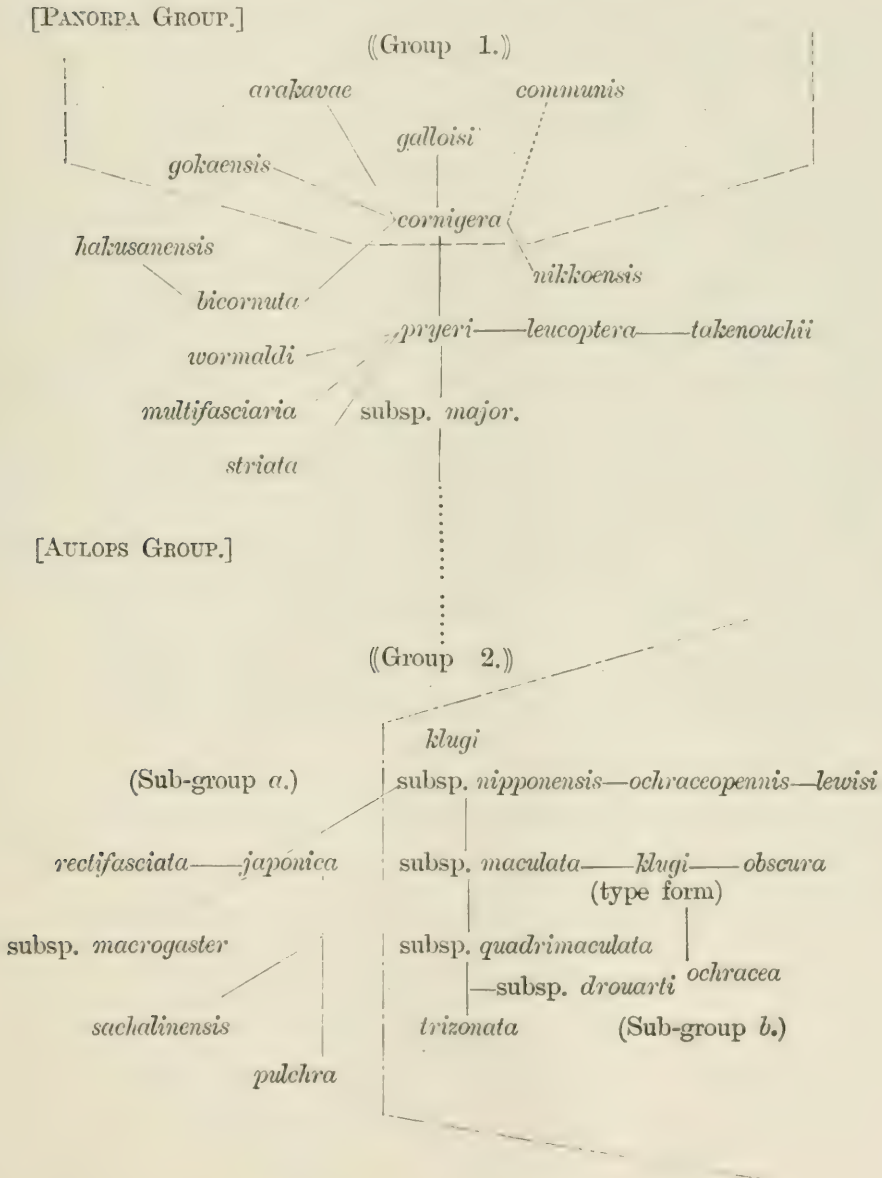
The following summary shows the modes of differentiation of wing markings in our *Panorpa*.

- I. Formation and modification of the pterostigmatal fascia.
  - a. Pterostigmatal spot developing anteroposteriorly so as to form the fascia.
  - b. Widening of the fascia.
  - c. Furcation on the edges of the fascia.
  - d. Straightening of edges.
- II. Formation and modification of the apical dark area.
  - a. Occurrence of spots or striae at the apical area.
  - b. Uniting of spots or striae into the apical dark area.
  - c. Changes in the internal edge.
  - d. Change of position of the apical dark area.
- III. Development of supplementary markings.
  - a. Development along the anterior or posterior margins, or the veins, of the wing.
  - b. Development anteroposteriorly from the costa to the posterior margin.
- IV. Formation of patches by interruption of stria or formation of stria by union of patches.
- V. Ochreous tinge of wings.
- VI. Coalescence, interruption, complication and separation of constituents of wing-markings.



Lastly I have drawn up the following phylogentic diagram of our species based on the above explained facts. (*Formosana*, *ophthalmica* and *sauteri*, of which I have not yet seen any specimen and which are imperfectly known to me, are omitted).

Phylogeny of wing-markings of *Panorpa* :



## 7. WING-MARKINGS OF PANORPODES.

*Panorpodes paradoxa* (Pl. XXXVI., fig. 1), the common species in Japan, has no wing-markings, and the pterostigmatal region is opaque or shaded slightly deeper than the ground colour. In some specimens it becomes still deeper, and in subspec. *stigmatica* the pterostigmatal region is tinged with piceous. This may possibly be the origin of the wing-markings in this genus; similar facts have been observed in *Panorpa*. On the other hand in *naevia* there occurs an apical dark margin, which is the origin of the apical marking. Next, as in fore wing of *decorata* subspec. *singularis* and both fore and hind wings of subspec. *limbata*, there occur three spots—one on the pterostigma, the next on the costa internal to the pterostigma and the third on the posterior margin. In certain forms of *limbata* there occurs another spot in the middle of the hind wing between the above stated anterior two spots, and the posterior one. The above stated three (or four) spots develop further to meet in the middle of the wing in the form of a Y, as is seen in certain forms of *limbata* and rarely in *singularis*. Further, some irregular supplementary markings may occur besides the above mentioned markings and lead to the typical form of *decorata*. *Confusa* is easily derived from typical *decorata*. *Notata* is a form rather different from any of the above stated species. However, let the outer and the posterior spot of the above mentioned three spots be preserved and another subapical fascia added, a form closely allied to *notata* would be obtained.

The phylogeny of the species of *Panorpodes*, so far as can be made out from the wing-markings, may be represented as follows:—

*Panorpodes* :

*paradoxa*—*naevia*,  
                   |  
 subsp. *stigmatica*,  
                   |  
 subsp. *singularis*,  
                   |  
 subsp. *limbata*—*notata*,  
                   |  
*decorata*—subsp. *confusa*.

## V. Habits.

### 1. PANORPA.

The habits of *Panorpa klugi* I have already described in detail in my former paper,\* and here I give only a brief account of the habits in general.

Panorpas are generally found in shady places, resting upon a leaf, the males bending up their terminal three segments; now and then they clean their antennae with their fore legs in a curious manner. They are also seen frequently elevating and depressing their wings alternately. They are rather dull insects and one can capture them without difficulty.

The economic value of the preying habit of *Panorpa* was long overestimated by entomologists both in Japan and abroad. KIRBY and SPENCE quoted in their "Entomology"† LYONNET's observation on *Panorpa communis*, which was found attacking a dragon-fly of ten times its own size. Even M'LACHLAN, honoured authority on Mecoptera, writes: "The perfect insects are active and predaceous, living on other insects, which they pierce with their long rostrum; with this instrument they will also inflict a sharp and momentary painful wound on the fingers, when incautiously handled."‡ POULTON§ tabulates Panorpas as preying upon a dead worm, Bibionid fly, Empid fly, Telephorid beetle, etc., and LUCAS|| tells us, he has seen the fly feeding upon a white grub. In Japan Prof. MATSUMURA, Mr. ONUKI and others have described *Panorpa* as preying upon living insects. However, in these examples, except that of LYONNET and M'LACHLAN, it is not stated that they were seen to catch their prey, so there is a possibility that they were feeding upon dead or injured insects.

An American author, FELT,¶ says on this point: "It is possible that *Panorpa* does attack and kill its own prey....yet they were not yet seen to touch a living, uninjured animal of any kind, and they were seen a number

\* MIYAKE: Journ. Coll. Agr. Imp. Univ. Tokyo, vol. iv., No. 2, pp. 117-130; pls. xiii, xiv (1912).

† KIRBY and SPENCE: Entomology vol. ii., p. 253 (1828).

‡ M'LACHLAN: Trans. Ent. Soc. Lond., 1868, p. 214.

§ POULTON: Trans. Ent. Soc. Lond., 1906, p. 402.

|| LUCAS: Ent., vol. xliii., No. 566, p. 186 (1910).

¶ FELT: Tenth Report. Inj. Ins. State, N. Y., p. 467 (1895).

of times in nature feeding upon partially decayed insects: neither the mandibles nor the maxillae of this insect are well adapted to piercing." Recently CAMPION\* reports *Panorpa* as feeding upon several dead insects and concludes that: "Although the timid scorpion-flies are undoubtedly carnivorous insects, they feed upon dead animal matter and do not catch and devour living prey." As far as my own observations go I can state that *Panorpa* does not attack nor touch living insects. This agrees well with the statements of FELT and CAMPION and may possibly be the truth. It is also very clear that *Panorpa* feeds upon other animal matter besides insects. This fact has not only been reported by many authors but also was confirmed by me. Consequently its economic value appears to be less than one might imagine.

*Panorpa klugi* destroys the petals of a sweet-william catchfly and feeds upon other vegetable matter as mentioned in my previous account of this insect, which observations I have repeatedly confirmed. Last year (1912), I saw, on Mt. Akagi, many scorpion-flies (*P. klugi*) swarming about a shrub and eagerly sucking its juicy fruits.

So far as I could observe in *P. klugi*, the food of the larva does not materially differ from that of the imago, except that it has not the vegetable feeding habit of the latter.

## 2. PANORPODES.

*Panorpodes* appears to be weaker and less active than *Panorpa*. I have repeatedly tried to rear it in captivity, but always failed, although I was fully experienced in feeding *Panorpa* and even *Bittacus*, they having lived over a month under my care. Several *Panorpodes* were seen to die on the day of capture or on the next day, and I only twice succeeded in keeping them alive three days. The main cause of death was due to the want of food, because the food, such as living or dead insects, pork, beef, fish, etc., that I fed *Panorpa* upon, they would not eat. Whether the species I experimented with are carnivorous appears doubtful.

*Panorpodes* are usually found in mountainous places, not only on the leaf, like *Panorpa*, but also on the rock or on the ground. Mr. YANO of the Imperial Forestry Experiment Station saw at Kita-akita-gun, Ugo, June 8,

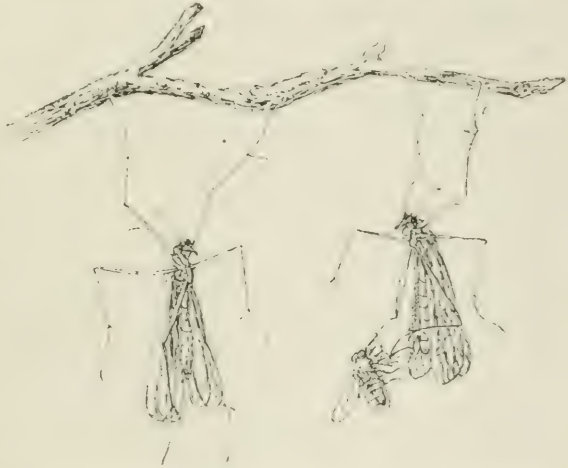
\* CAMPION: Ent., vol. xlv., No. 594, p. 322 (1912).



1912; many of the insects swarming around a lamp in the night, attracted by the light. He brought me seven specimens, which were all males of *Panorpodes paradoxa*. It therefore appears that *Panorpodes* has a phototaxic character.

### 3. BITTACUS.

*Bittacus* prefers still more shady places than *Panorpa*. It does not usually rest upon a leaf like *Panorpa*, but it suspends itself from a branch or a leaf by its long fore legs. Occasionally, however, it uses only one leg or the middle pair instead of the fore. In those cases its body hangs down, the head extended forward with a slight downward inclination. The wings are drooped alongside the body, the middle femora stretched laterally and the hind femora hang almost vertically, while the tarsi are anteriorly curved. If a wind blows or the branch is moved it waves



Text-figure 6.—Natural position of *Bittacus nipponicus*.  
Nat. size.

like a pendulum. It remains in this position for quite a long time. If a small insect, such as a house-fly, comes within the reach of the insect it tries to seize it. For this purpose the fourth and fifth tarsal joints are armed with special teeth, the fifth closing down upon the fourth (see page 278 and also Pl. XXIX., figs. 12 a, 12 b; 13 a, 13 b). If one trial fails it instantly makes a second or third; if it does not succeed and the prey flies away it usually resumes its calm attitude, and very rarely does it pursue its victim. When the insect is caught its body is soon pierced and sucked dry. When the feast is ended it lets fall the corpse of the unfortunate victim, or not infrequently holding the lifeless body with its hind legs it hangs down quietly as usual. Possibly this is done to allure the opposite sex, for I have seen females

come and try to take away the bait, whereupon the male attempted to capture the female. Copulation may take place by the insects facing each other ventrally, both suspending from the branch with their abdominal extremities in contact.\* The oviposition is, so far as observed, like the European and American species, simply dropping the egg on the ground one by one at random. In one case however I have seen a female alight on the ground where I found a few eggs after it departed.

Though *Bittacus* is reported by many authors to touch nothing but living insects, this is not, as far as our species are concerned, without exception. Of course living insects are its main food, still it will often devour dead flies or suck decayed leaves, soil, and sometimes a drop of water. Moreover, I have once seen *Bittacus* attack its own dead as *Panorpa* does. *Bittacus* appears to avoid excessive moisture and when kept too moist a fungus seems to attack the legs, which then become entangled and the insect soon dies, being unable to move. When a number of *Bittacus* are placed in a cage, with excessive moisture in and around it, they soon entwine their legs with one another and drop down upon the ground and die. The most common species, *Bittacus nipponicus*, captures house-flies or other insects of equal size, but it does not attempt to capture the larger insects such as *Sarcophaga*, *Eristalis*, bees, etc., nor smaller insects like mosquitoes etc. In this it differs greatly from the Australian species (*Bittacus australis*) which is reported by JARVIS† to capture and prey on bees and a day-moth (*Phalaenoides tristifica*).

## VI. Life-History.

The life-history of *Panorpa klugi* I have already published in my former paper.‡ The egg of *Panorpa klugi* is fuscous yellow, with net-like depressions. Length 0.9–0.97 mm.; width 0.59–0.75 mm. The egg hatches out on the eighth day after deposition. The newly hatched larva is creamy white with very remarkable pinkish eyes; length 3–6 mm. It has biting mandibles and maxillae with four-jointed palpi. The antenna is four-jointed. The prothorax bears dor-

\* In one case I have seen the two insects in copulation on a vertical wall, their bodies were placed quite in opposite directions from each other, touching only at their abdominal extremities.

† JARVIS: Sci. Nat. Study, Dec. 7; p. 18 (1912).

‡ MIYAKÉ: Journ. Coll. Agr. Imp. Univ. Tokyo, vol. iv., No. 2 (1912).

sally a very prominent chitinous transverse shield. The remaining segments each bear an elliptical shield. Each shield bears typically a pair of large, two smaller and a pair of still smaller setae. The large setae on the first to the tenth abdominal segment are pilose and annulated. The last abdominal segment bears only a single median seta. Each thoracic segment is provided with a pair of cylindrical jointed legs, and the first to the eighth abdominal segment each have a pair of cylindrical prolegs, so that the larva has eleven pairs of legs in all. On this point it bears a great resemblance to the Tenthredinid larva. After the first moult the annulated setae of the first to the seventh abdominal segment are reduced to mere rudiments. After moulting seven times (probably) in fifteen days it becomes full grown. The larva is now slightly fuscous tinged with a rosy colour. The larva, like the adult, is carnivorous and preys on meat, wounded insects, etc., but does not seem to attack healthy living insects so far as I observed. The last stage lasts for several days, and the larva begins to burrow deeper into the ground, making a small cell of earth. It lies rolled up in it until it pupates. The pupa is of the type of *Pupa libera*. The entire body is curved first ventrally and then dorsally. The compound eyes are large and three ocelli indicated. The antennae are long, filiform, consisting of 42 or more joints. The mouth-parts are rather similar to those of the larva but more elongated. Three long thoracic legs are present. Two pairs of spatulate wings are found on either side of the body. The abdomen is conical, the terminal segment differs in sexes like in the adults. In the male the cheliferous segment and chelae are not distinctly differentiated. The pupal stage lasts for six or seven days. *Panorpa klugi* has two generations in a year; it passes the winter in the larval form within the cell under ground, and pupates at the end of April or beginning of May, and the perfect insect appears in that month. This insect lays eggs which soon hatch out, and the larvae pupate at the end of July or beginning of August and shortly afterward the adults of the first generation appear. The newly emerged insects deposit the eggs at the end of August or in September, and the larvae hatched therefrom attain maturity at the middle of October and pass the winter. These appear as adults in May of the next year. Some other species, such as *japonica*, *trizonata*, *pygeri*, etc. very probably have similar life-histories. There may also be certain one-brood forms, since I have seen *wormaldi* only at one definite season (May or June) of every year.



In the breeding of *Panorpodes* I have repeatedly failed; I could not obtain its laid eggs. However the matured eggs contained in the ovary are yellowish and oval with the length 0.65–0.78 mm. and width 0.43–0.56 mm. The insect has almost certainly only one generation in a year. In the vicinity of Tokyo it appears in June and July and in mountainous places in midsummer.

Of *Bittacus* I have succeeded in obtaining eggs from *B. nipponicus*. They are subcuboidal and reddish brown; chorion is granulate (Pl. XXXII., fig. 8). Length 0.91–0.95; width 0.78–0.82. They are therefore larger than those of the American species (*B. strigosus* and *pilicornis*), of which FELT describes the length as 0.8125 mm. and the width as 0.6875. It passes winter in egg-state and very probably hatches in the following spring and pupates in June. Imago appears in July\* and lives until August.

## Part II. SYSTEMATIC.

Of the Mecoptera of Japan, including Formosa, Corea and Sakhalin, more than forty species have hitherto been described. As the chief criteria of distinguishing each species the wing-markings were generally used. These, however, being highly variable, some authors directed their attention to other characters, thus RAMBUR attached considerable importance to the number of teeth in the claws, and M'LACHLAN depended chiefly upon the male genital ventral appendage. Claws are, as far as I have observed, subjected to much variation, like the wing-markings, and can never be trusted. The appendage, however, appeared to me to be rather fixed in each species, until my breeding experience of *Panorpa klugi* showed me, that even the forms of the appendage may vary amongst individuals of the same species; also different methods of preservation and degree of maturity cause a certain amount of modification to them. Being so, it is an extremely difficult thing to find out a fixed standard in Mecoptera for taxonomic purposes.

If we study the range of variation of the wing-markings with respect to each species, they represent certain typical characters peculiar to each species, which can, to a certain extent, be utilized for taxonomic purposes. Likewise in the forms of claws—though the number of teeth in claws cannot

\* There is a certain species (probably new) which appears early in May.



determine each species respectively, when taken together with other characters, such as the curvature of claws, forms of teeth, etc., often give very valuable aid to taxonomy. Further, the number of branchlets of the first branch of the radial sector, which ENDERLEIN adopted in distinguishing genera, furnish, to a certain extent, an additional character to each species, so that they also should be taken into consideration.

For these reasons, I have in the following descriptions regarded all these characters and endeavoured to sum up these peculiarities relating to each species. I then studied the modes of variations in these peculiarities, and after this I settled the typical character of each species. By this method the number of species hitherto described from Japan were reduced to 39 species. These together with four species and five subspecies, which I consider to be new to science, are tabulated and described in the following pages.

Even these results are very far from satisfying me. The distinct determination of species must be based on the life-history and the anatomy of genitalia (of male) of each species. For the former my knowledge is still imperfect, and for the latter some species are not represented in sufficient number in my collection to enable me to make the necessary dissections.

As genera occurring in Japan I have adopted four—*Panorpa*, *Panorpodes*, *Leptopanorpa* and *Bittacus*, though besides these, *Aulops*, *Campodotecnium* and *Diplostigma* have also been erected for our fauna. Of these latter genera, *Aulops* is, as stated before, to be included in the genus *Panorpa*; *Campodotecnium* cannot be proposed at least for any of our species, even if its generic value be recognized, which is in fact very doubtful, since only one character seems to be peculiar to the genus. The characters of *Diplostigma* are too insufficient to enable me to recognize it as a distinct genus.

Almost all authors have hitherto accepted all our species as belonging to a single family, that of Panorpidae. M'LACHLAN and ENDERLEIN's proposal of two families seems to me rather unnecessary. I regard them as subfamilies in this paper.

The body colour of Mecoptera is different in living and dead specimens, especially, the colour of the pleural and intersegmental membranes, which often gives to the specimen a quite different appearance after death. The colours mentioned in the following descriptions are exclusively those of the dried specimens.

The ground colour of wings happens also occasionally to vary, though it is usually fixed in each species, consequently the use of it in taxonomy is apt to lead to faultiness of description. However, as it is broadly fixed, I use it, for convenience, in the key to the species of *Panorpa*.

The morphology of claws which are described under each species was based on observations of the left-side claw of the left fore leg. Of course, in different individuals as well as in the different legs of the same individual there are often some variations, so that what is stated beyond, relating to claws, should not be too much relied upon.

Of the four genera occurring in Japan, the genus *Leptopanorpa* is still unknown to me; I have not yet obtained any specimen, nor have I seen any in Japan. There are also four species in *Panorpa* and one in *Panorpodes*, which are only known to me through descriptions. For these I have reproduced their original descriptions.

The interesting genus *Boreus* which occurs in Europe and America has not yet been found in Japan, though our country is very rich in Mecoptera. I have often searched for it, but in vain, so that possibly it does not occur in this country.

The genera and species of Mecoptera occurring in Japan are as in the following table:—

Systematic List of Genera and Species  
described in this Paper, showing their Geographical Distribution.

Species.	Localities.	Hokkaido.	Honshu.	Shikoku.	Kyushu.	Formosa.	Other Localities.
Family PANORPIDAE. Subfamily Panorpinæ. Genus <i>Panorpa</i> .							
1. <i>Panorpa cornigera</i> M'Lach.			×		×*		Siberia†
subspec. <i>fulvicaudaria</i> n. subsp.			×				
2. <i>P. communis</i> L.			×		×	×	Europe
3. <i>P. golaensis</i> Miyake.					×		

\* According to Prof. MATSUMURA.

† According to Prof. NAVAS.

Species.	Localities.	Hokkaido.	Honshiu.	Shikoku.	Kiusiu.	Formosa.	Other Localities.
4. <i>Panorpa galloisi</i> Miyake.			×				
5. <i>P. arakavae</i> n. sp.			×				
6. <i>P. ophthalmica</i> Navas.						×	
7. <i>P. formosana</i> Navas.						×	
8. <i>P. sauteri</i> Peters.						×	
9. <i>P. japonica</i> Thunb.			×		×		
subspec. <i>macrogaster</i> M'Lach.		×					
10. <i>P. pulchra</i> Miyake.				×	×		
11. <i>P. rectifasciata</i> Miyake.			×				
12. <i>P. sachalinensis</i> Mats.							Sakhalin*
13. <i>P. bicornuta</i> M'Lach.			×		×		
14. <i>P. hakusanensis</i> n. sp.			×				
15. <i>P. pryeri</i> M'Lach.			×		×		
subsp. <i>major</i> Miyake.			×				
16. <i>P. leucoptera</i> Uhl.		×					
17. <i>P. wormaldi</i> M'Lach.			×				
18. <i>P. striata</i> Miyake.			×				
19. <i>P. multifasciaria</i> Miyake.			×		×		
20. <i>P. takenouchii</i> Miyake.			×	×	×	×	
21. <i>P. nikkoensis</i> Miyake.			×				
22. <i>P. klugi</i> M'Lach.			×		×		
subsp. <i>nipponensis</i> Navas.			×				
„ <i>drouarti</i> Navas.			×				
„ <i>maculata</i> n. subsp.			×				
„ <i>quadrifasciata</i> n. subsp.			×				
23. <i>P. trizonata</i> Miyake.			×				
24. <i>P. ochracea</i> Miyake.			×				
25. <i>P. obscura</i> Miyake.			×				
26. <i>P. ochraceopennis</i> Miyake.			×				
27. <i>P. lewisi</i> M'Lach.			×				
Genus <i>Panorpodes</i>							
28. <i>Panorpodes paradoxus</i> M'Lach.			×		×		
subsp. <i>stigmatica</i> n. s.p.			×				
29. <i>P. naevia</i> Navas.			×				
30. <i>P. decorata</i> M'Lach.			×				

\* According to Prof. MATSUMURA.

Species.	Localities.	Hokkaido.	Honshu.	Shikoku.	Kyushu.	Formosa.	Other Localities.
	subsp. <i>singularis</i> Miyake.		×				
	subsp. <i>limbata</i> (Navas).		×				
	„ <i>confusa</i> n. s.p.		×				
31.	<i>Panorpodes notata</i> Navas.		×				
	Genus <i>Leptopanorpa</i>						
32.	<i>Leptopanorpa ritsemae</i> M'Lach.				×		
33.	<i>L. sieboldi</i> M'Lach.				×		
	Subfamily <i>Bittacinae</i> .						
	Genus <i>Bittacus</i> .						
34.	<i>Bittacus nipponicus</i> Navas.		×				
35.	<i>B. laevipes</i> Navas.		×		×	×	
36.	<i>B. sinensis</i> Walk.		×		×	×	China
37.	<i>B. quaternipunctatus</i> End.		×				Corea
38.	<i>B. takaoensis</i> n. sp.		×				
39.	<i>B. marginatus</i> n. sp.		×				
	Species insufficiently known.						
40.	<i>Panorpa hageni</i> Navas.		×				

### ORDER MECOPTERA.

Head prolonged into a deflexed rostrum, with the mandibulate mouth-parts at the apex. Wings four, elongate, subequal, naked, with venation almost of the typical form, connected by numerous cross veins. In a few cases wings are absent or rudimentary. Proventriculus internally arranged with special setae. Metamorphosis complete; larvae caterpillar-like, with eleven pairs of legs.

A single family present.†

#### FAMILY Panorpidæ.

Antennæ filiform or submoniliform; three ocelli usually present; rarely absent; mandibles elongate with sharp teeth at the apex; maxillae bilobed, with

\* According to Prof. MATSUMURA.

† Some authors propose two families:—*Panorpidæ* and *Boreidæ* by M'LACHLAN; *Panorpidæ* and *Bittacidæ* by ENDERLEIN; etc.



the five-jointed palpi. Prothorax narrow. Legs slender, the coxa with another supporting piece. Wings mostly marked with black; in repose folded longitudinally, roof-shape. Male with appendages on the genital segment.

SUBFAMILY I. PANORPINAE.

*Cu*<sub>1</sub>. partly fused with the media only in the hind wing; claws paired.

*Key to the genera occurring in Japan.*

- A. First abdominal segment modified.
  - a. Claws ventrally with sharp teeth. . . . . *Panorpa*.
  - b. Claws ventrally without teeth. . . . . *Panorpodes*.
- B. First abdominal segment unmodified. . . . . *Leptopanorpa*.

Genus *Panorpa* Linnaeus (1758).

*Aulops* Enderlein (1910).

Antennae long; rostrum moderately pointed. Wings moderate, usually with the pterostigmatal fascia; subcosta usually connected with the costa by a single cross vein. Legs moderately long; claws ventrally with sharp teeth. Abdomen cylindrical in the male and conical in the female; first abdominal segment modified. Male with the forceps at the extremity. Adult preys on dead animal matter or plants.

*Key to the species found in Japan.*

- A. Subcosta in the fore wing extending to the pterostigma.\* . . . .
  - . . . . . Group I. (*Panorpa* End.)
  - a. Abdomen in ♂ without process on the posterior margin of the sixth segment.
    - a<sup>1</sup>. Third abdominal segment in ♂ without very long tube.
    - a<sup>2</sup>. Branches of appendage† slender, remote from each other. . . .
      - . . . . . *communis*.
    - b<sup>2</sup>. Branches of appendage broad, almost united with each other; an

\* For *formosana*, *ophthalmica* and *sauteri*, of which I have not yet seen any specimen, I rely only on the figures represented in the original description.

† "Appendage" means the ventral appendage of ♂.

elongated triangular space being left between them at the base.

.. .. . *formosana*.

- c<sup>2</sup>. Branches of appendage very broad, dilated, and each curved towards the body axis, the internal margins uniting with each other; a round space left between them at the base.

.. .. . *ophthalmica*.

- b<sup>1</sup>. Third abdominal segment of ♂ with a long tube... *sauteri*.

- b. Abdomen in ♂ with a process on the posterior margin of the sixth segment.

- a<sup>1</sup>. Wings with only a small pterostigmatal spot. .. *galloisi*.

- b<sup>1</sup>. Wings with a complete or incomplete pterostigmatal fascia; or rarely with some small accessory patches. .. *cornigera*.

- c<sup>1</sup>. Wings with a complete pterostigmatal fascia and a complete internal fascia in the fore wing. .. *gokaensis*.

- d<sup>1</sup>. Wings with a **Λ**-shaped pterostigmatal fascia.. *arakavae* n. sp.

- B. Subcosta in the fore wing extending to the costal margin scarcely beyond its middle... .. Group II. (*Aulops* End.)

- a. Wings with ochreous tinge.

- a<sup>1</sup>. Wings with the pterostigmatal fascia.

- a<sup>2</sup>. Branches of appendage of ♂ slightly approximated towards the apex, or almost parallel with each other.

- a<sup>3</sup>. Outer edge of the pterostigmatal fascia of both wings always sharply defined; inner edge of the pterostigmatal fascia of fore wing furcate; abdomen of ♂ abruptly attenuated from the 7th towards the extremity. .. *ochraceopennis*.

- b<sup>3</sup>. Both edges of the pterostigmatal fascia of both wings sharply defined; or the outer edge only furcate; abdomen of ♂ gradually attenuated towards the extremity.

- a<sup>4</sup>. With the pterostigmatal fascia only, furcate or sharply defined; some patches or irregular oblique striae internal to the fascia often present. .. *klugi*.

- b<sup>4</sup>. With another broad fascia internal to the pterostigmatal fascia... .. *trizonata*.

- b<sup>2</sup>. Branches of appendage of ♂ diverged towards the apex.

- a<sup>3</sup>. Pterostigmatal fascia narrow, sharply defined; size large, body ochreous. . . . . *ochracea*.
- b<sup>3</sup>. Pterostigmatal fascia broad, the outer margin with a short branch; size middle; body piceous. . . . . *klugi* (var. form).
- c<sup>3</sup>. Pterostigmatal fascia broad, slightly wavy, sharply defined; size small; body testaceous. . . . . *obscura*.
- b<sup>1</sup>. Wings without the pterostigmatal fascia; a small pterostigmatal spot present. . . . . *lewisi*.
- b. Wings hyaline; occasionally with slight ochreous tinge at the basal region.
  - a<sup>1</sup>. Wings with the complete pterostigmatal fascia; rarely the costal half only present, in that case no accessory spots or striae present, except the apical patch and costal suffusion.
  - a<sup>2</sup>. Pterostigmatal fascia broad.
  - a<sup>3</sup>. Pterostigmatal fascia evenly broad.
    - a<sup>4</sup>. Pterostigmatal fascia with the irregular or furcate outer edge; one or two accessory spots internal to the fascia present. . . . . *japonica*.
    - b<sup>4</sup>. Pterostigmatal fascia sharply defined on both edges; no accessory spot present; wings usually ochreous at the basal region. . . . . *rectifasciata*.
    - c<sup>4</sup>. Pterostigmatal fascia with the irregular or furcate outer edge; Y-shaped accessory patch often with more patches internal to the fascia present. . . . . *pulchra*.
  - b<sup>3</sup>. Pterostigmatal fascia narrowed at the middle; (wings of ♂ with slight ochreous tinge) . . . . . *sachalinensis*.
- b<sup>2</sup>. Pterostigmatal fascia narrow.
  - a<sup>3</sup>. Basal half of costa suffused with black.
  - a<sup>4</sup>. Pterostigmatal fascia only present.
    - a<sup>5</sup>. Sixth segment without a process; seventh with two spines. . . . . *bicornuta*.
    - b<sup>5</sup>. Sixth segment with a process; seventh without spines. . . . . *cornigera* (var. form).
  - b<sup>4</sup>. With numerous fasciae besides the pterostigmatal fascia. . . . . *hakusanensis* n. sp.

- b<sup>3</sup>. Basal half of costa not suffused with black, though the subcosta and radius may be suffused with black.
- a<sup>4</sup>. Pterostigmatal fascia **Λ**-formed.
- a<sup>5</sup>. Markings not deeply coloured; veins mostly whitish.. .. *wormaldi*.
- b<sup>5</sup>. Markings black; veins mostly blackish.
- a<sup>6</sup>. Many short streaks between each vein along the apex present.. .. *multifasciaria*.
- b<sup>6</sup>. No short streaks between each vein along the apex present.. .. *striata*.
- b<sup>4</sup>. Pterostigmatal fascia as usual; rarely incomplete.
- a<sup>5</sup>. Size large; ochreous area of the dorsal side of thorax small; two black striae of rostrum very broad... .. *pryeri*.
- b<sup>5</sup>. Size small; ochreous area of the dorsal side of thorax large; two black striae of rostrum narrow... *leucoptera*.
- b<sup>1</sup>. Wings with the incomplete or irregular pterostigmatal fascia, consisting of three spots; many large quadrate patches present. *takenouchii*.
- c<sup>1</sup>. Wings without the pterostigmatal fascia; a small pterostigmatal and two costal spots present. .. .. *nikkoensis*.

Group I. (*Panorpa* End.)

1. *Panorpa cornigera* M'Lachlan.

*Hoso-obi-shiriagemushi*.

(Pl. XXXVI., figs. 5, ♂, 6, ♀; claw—text-fig. 2, a; appendage—Pl. XXX., fig. 13a.)

*Panorpa cornigera* M'Lach., Bull. Soc. Ent. Suiss., 1887, p. 404; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 4; Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

Body totally black; eyes and palpi testaceous; legs with the coxa and trochanter black, the femur and tibia ochreous and the extremity of the latter and tarsus dusted with testaceous; claws evenly curved with the apex more produced than the teeth; prominent teeth four.



Wings hyaline, with the apex acutely elliptical; the subcosta usually extending to the pterostigma; frequently however it is variable and in some cases is ended as in most of our species; a small blackish patch at the origin of the radial sector; pterostigmatal fascia narrow and oblique, occupying anteriorly the inner half of the pterostigma; in some specimens the apex is narrowly margined with black; one or two fine, curved fasciae between the pterostigmatal fascia and the apex occasionally present; longitudinal veins ochreous at the basal area and fuscous at the outer area; cross veins ochreous; first branch of radial sector with three branchlets.

In the male the posterior margin of the third abdominal segment is scarcely produced in the middle; second to fifth segment rather short, cylindrical; sixth stout, conico-cylindrical, the posterior margin produced into a median process; seventh to last piceous; seventh and eighth each as long as the sixth, but narrower and conical; the dorsal surface of seventh with a sinuation in the middle, corresponding to the process of sixth; eighth truncate posteriorly; cheliferous segment small; chelae rather small, crossing each other in an oblique direction;\* branches of appendage (ventral) long, linear, slightly approximating each other at the base and the apex, and separating at the middle; the distal half bent downward between the lateral portion of the segment; no long stalk of the appendage present; females with the terminal segments telescoped inward; appendages black.

Length of body: ♂ 12 mm.; ♀ 11-17 mm.

Expanse: 28-32 mm.

Loc.: Nikkō; Konsei-tōge; Mt. Nasu; Fukui; Echigo; Harima; Kiushiu (according to Prof. MATSUMURA); Siberia (according to NAVAS).

Time of Appearance: May to August.

Subspecies *fulvicaudaria* n. subsp.

Rostrum, process of the sixth abdominal segment, and seventh to last abdominal segment reddish ochreous.

Length of body: ♂ 12 mm.

Expanse: 27 mm.

\* I say this of the dried specimen.

Type: A male specimen in my collection, captured at Harima, on May 22nd, 1900, and sent to me by Mr. NAKAHARA.

The specimen bears quite the same venation as those in the *Aulops* group.

## 2. *Panorpa communis* Linnaeus.

### *Madara-shiriagemushi.*

(Pl. XXXVI., fig. 21, ♂; claw—text-fig. 2, b; appendage—Pl. XXXI., fig. 11.)

*Panorpa communis* Linn., Faun. Suec. p. 384 (1761); Syst. Nat. I., pars ii., p. 915 (1767); Westwood, Trans. Ent. Soc. Lond., vol. iv., p. 185 (1846); Walker, List. Neurop. Coll. Brit. Mus., pt. ii., p. 457 (1853); McLach., Trans. Ent. Soc. Lond., 1868, p. 214; Trans. Ent. Soc. Lond., 1869, p. 63, pl. iv., fig. 3; Matsumura, Senchu-zukai (Thousand Insects of Japan), vol. i., p. 164, pl. xi., fig. 6 (1904); Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2 (1908); Entomologist, vol. xlv., No. 574, p. 91 (1911).

Body fuscous; frons between the eyes black; vertex and occiput ochreous; eyes ochreous or testaceous; antennae piceous, with the basal joint yellow; rostrum ochreous, tinged laterally with testaceous; palpi ochreous; prothorax fuscous, with the posterior margin ochreous; meso- and meta-thorax with an ochreous dorsal fascia; legs greyish yellow; claws evenly curved, with the apex more produced than the teeth; prominent teeth usually four.

Wings rather narrow, hyaline, very faintly tinged with fuscous; apex elliptical; markings fuscous; a small spot in the middle of the wing near the base; an outwardly oblique transverse fascia, formed by the union of two patches, before the middle; a small costal spot at the middle of wing; pterostigmatal fascia narrower and posteriorly forked, representing the figure of a **A**; the apical dark area with one or two irregular spots of the ground colour within; longitudinal veins and some basal cross veins fuscous; rest of cross veins colourless; first branch of radial sector bears four branchlets in the two Japanese specimens before me, though European specimens in my possession bear three branchlets.

In the male, abdomen with the pleural membranes and ventral side yellowish; second to fifth segment cylindrical, almost equal in length; third segment hardly projects at the median posterior margin as many of the

Japanese species do; sixth stout and conico-cylindrical; seventh and eighth slender, conical, each as long as the sixth; the posterior margin of the eighth obliquely truncate; cheliferous segment testaceous, with the basal portion almost triangular; chelae rather short, crossing each other in a very oblique direction; appendage (ventral) long, linear, without stalk, slightly apart towards the middle, approximating, however, towards the base and apex; female with the terminal three segments ochreous; appendages piceous.

Length of body: ♂ 12 mm.; ♀ 11 mm.

Expanse: 33–34 mm.

Loc.: Towada, Mutsu; Ōshima, Kiushiu; Formosa.

Time of Appearance: July.

Distribution: Europe; Japan.

This species is rather rare but widely distributed in Japan. The Japanese species represent, like the European, several variations in the wing-markings, which are, speaking generally, more pronounced in the former. In the extreme case the pterostigmatal fascia is very prominent and **Λ**-shaped and all internal markings rather obscure. Such forms are commonly found in Formosa. It is almost certain that NAVAS' *Panorpa formosana* is a species closely allied to this form and therefore can be considered as a varietal form of the present species. Of course *formosana* as well as some of my *communis* from Japan differ somewhat from the type form, so that they may sometimes be recognized as another species. However, from a long series of European and Japanese forms of *communis* before me, I could not discover any distinct difference that can properly separate them.

### 3. *Panorpa gokaensis* Miyake.

*Maye-futasuji-shiriagemushi.*

(Pl. XXXVI, fig. 3, ♀; claw—text-fig. 2, c; appendage—Pl. XXXI, fig. 15.)

*Panorpa gokaensis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 193, pl. xi., fig. 3 (1910); Entomologist, vol. xlv., No. 574, p. 91 (1911).

Body totally black: antennae, rostrum and palpi black; legs fuscous yellow, with the extremity of each joint and some terminal tarsi fuscous;



claws testaceous; dorsal body of claws rather highly curved, with the apex produced as long as the teeth, which are four in number.

Wings hyaline, with the apex elliptical; pterostigmatal fascia rather narrow; in the fore wing a likewise narrow blackish antemedial fascia is present, slightly oblique in direction contrary to that of the pterostigmatal fascia; a rather small blackish apical patch, with well defined inner edge; costal, subcostal and radial veins black; the remaining veins fuscous yellow except where they cross the fascia, where they are black; first branch of radial sector with three branchlets.

Abdomen rather short, black; in the male the posterior third dorsal segment is scarcely produced into a lobe; sixth cylindrical, dorsally with a process; seventh narrower and longer than the sixth and almost equal to the eighth; cheliferous segment rather smaller but stouter than in *P. japonica*;\* lateral portions very stout and rounded; chelae shorter than the segment, almost straight, being very slightly curved towards the extremities, which are testaceous; they are usually crossed in a very oblique direction; appendage rather long, slightly curved, approximating at the base and the apex.

Length of body: ♂, ♀ 12 mm.

Expanse: ♂ 30 mm.; ♀ 33 mm.

Loc.: Goka-no-shō, Kiushiu.

Time of Appearance: May.

A male and a female specimen captured by the author, on May 27, 1908.

#### 4. *Panorpa galloisi* Miyake.

*Futaten-shiriagemushi*.

(Pl. XXXIV., fig. 10 a, ♂; abdomen—fig. 10 b; appendage—fig. 10 c.)

*Panorpa galloisi* Miyake, Entomologist, vol. xliv., No. 574, p. 93 (1911).

Body blackish piceous; rostrum blackish, slightly shorter than that of our other *Panorpa* species; palpi piceous; legs testaceous.

Wings rather broad (broadest at the pterostigmatal region), whitish with fuscous veins, with the apex acutely elliptical; the only conspicuous markings (fuscous in colour) are of somewhat quadrate form in the fore wing and of a triangular shape in the hind wing and are situated at the pterostigma, which

\* I quote the species for comparison, as it is very common.



is somewhat opaque, occupying the middle one-third; three very insignificant spots found in the fore wing placed obliquely from the pterostigma to the posterior margin, the first situated at the middle of the wing and the last at the posterior margin.

In the only known specimen (male) the posterior margin of the third abdominal segment is, so far as I can observe, formed like the other segments, and not produced into a median lobe, as in most of our *Panorpa*. The fifth and sixth segments stout and obconical, the latter is very conspicuous, and bears a short process like *cornigera* at the middle of the posterior margin; seventh slender, longer and cylindrical; eighth much more slender and cylindrical and almost equal in length to the former; cheiliferous segment stout and rounded, the chelae shorter than the segment; branches of appendage long and almost parallel, except towards the end, where they slightly approach each other.

Length of body: ♂ 11 mm.

Expanse: 30 mm.

A single male specimen (type) only is known and in the possession of Mr. EDMÉ GALLOIS, who captured it at Chuzenji, Nikkō, on July 27th, 1910.

### 5. *Panorpa arakavae*\* n. sp.

*Arakawa-shiriagemushi.*

(Pl. XXXVI., fig. 8, ♂; claw—text-fig. 2, d; appendage—Pl. XXXI., fig. 12.)

Body totally black; eyes piceous; legs ochreous; claws evenly curved, with the apex produced over the teeth; prominent teeth four.

Wings rather broad, hyaline, with the apex elliptical; the basal region of the fore wing slightly tinged with ochreous; black markings as follows:—an irregular narrow fascia on the stalk of radius; an inwardly angulate fascia at the juncture of radial sector; the fascia is reduced into two obscure spots in the hind wing; a short fascia in the middle of costa running posteriorly to the middle of wing; pterostigmatal fascia narrow, forked posteriorly at the middle of wing, so that it represents the form of a **Λ**; a rather straight fascia from the costa to the posterior margin; apex narrowly margined with

\* Dedicated to Mr. M. ARAKAWA, who captured the specimen.

black; longitudinal veins except the basal portion blackish fuscous; the rest and cross veins pale; first branch of radial sector with three branchlets.

Abdomen (in the specimen, which is male) very slender; second to fifth segment short, cylindrical, nearly equal in length; sixth large, with a dorsal process as in *cornigera*; seventh and eighth very slender; cheliferous segment as in *cornigera*; chelae large, crossing in a very oblique direction; appendage very slender, the branches widely distant from each other in the middle and slightly approximated on the apices.

Length of body: ♂ 13 mm.

Expanse: 29 mm.

Loc.: Sōhon-tōge, Shinano (?).

Type: A single male specimen in my collection, captured by Mr. ARAKAWA, on July 4th, 1912.

## 6. *Panorpa ophthalmica* (Navas).

*Taiwan-madara-shiriagemushi*.

*Campodotecnium ophthalmicum* Navas, Rev. Rus. Ent., 1911, No. 1, p. 3.

I have only an unique female specimen of this species, sent by PETERSEN, and cannot make a sufficient description. The following is the reproduction of NAVAS' original description:—

“Simile *angustipenni* Westw. Caput nigrum, prostomate longo, testaceo, nitente; palpis concoloribus; antennis nigris, primo articulo testaceo. Thorax fusco-niger, inferne fulvus, superne in meso- et metanoto lobis lateralibus rufis. Abdomen fuscum, ventre et ultimis segmentis testaceis. In ♂ processu dorsali 3-i segmenti parum elevato, acuto, ultra dimidium 4-i producto; 6-o segmento inflato, inferne fusco, superne basi semicirculariter emarginato, apice testaceo; 7-o brevior, angusto, apice dilatato, testaceo, lateraliter infuscato; 8-o longitudine 7-o aequali, testaceo, apice oblique truncato; 9-o brevi, inflato, forcipe dentibus interne ante medium bilobatis, apice angustatis; furca petiolo amplo, ramis latis, triangularibus fuscis, basi emarginatis, spatium cuneiforme liberantibus. Pedes fulvo-ferruginei, tarsorum articulis apice anguste fuscatis. Alae angustae, membrana hyalina, flavido sordide tincta; venis fusco-nigris; venulis in medio basilari alae fuscis, in apice albis, vel interne fuscis, externe albis. Ala anterior ita fuscumaculata: 1-o atomo pupillaeformi inter ramos cubiti;

2. umbra ad extremum venae postcubitalis (analis); 3. fascia angusta obliqua sinuosa completa, ante medium; 4. alia fascia ad medium a costa incipiente et ante thyridium desinente, vel ad thyridium (in ♂ cum anteriore confluyente), ad ejus extremum iterum atomus pupillaeformis; 5. fascia obliqua stigmalis, ad costam dilatata, retrosum fucata, et ante divisionem alio atomo pupillaeformi nigro-notata; 6. fascia angustissima sinuosa, a dilatatione costali anterioris usque ad marginem internum et posteriorem sequentis (in ♂ ad medium fucata, ramo interno brevi nec marginem attingente); 7. apice toto fusco. Ala posterior tribus item pupillis notata: 1-a pone furcam procubiti, 2-a pone ramum primum sectoris radii (in ♂ intra maculam fuscam), 3-a ante divisionem fasciae mediae. Praeterea ita fusco-maculata; 1. macula inter cubitum et postcubitum (in ♀ marginem posteriorem attingente); 2. fascia stigmalis oblique, retrosum fucata; 3. fascia anteapicali angustissima, medio interrupta, postice in duas lineas divisa (in ♂ interna nebulosa); obsoleta; 4. fascia apicali."

	♂	♀
"Long. corp. (a vertice ad abdom. apicem) 16 mm.	16 mm.	10,5 mm.
" " „ al. anter.	14,5 „	13,5 „ "
" " „ poster.	13 „	12 „ "

"Patrie: Tainan (Formose). Dans ma collection."

## 7. *Panorpa formosana* (Navas).

*Taiwan-shirigemushi.*

*Campodotecnum formosanum* Navas, Rev. Rus. Ent., 1911, No. 1, p. 3.

*Panorpa formosana* Petersen, Ent. Mittel., Bd. i., No. 7, p. 198 (1912).

I have not yet obtained a specimen of this species so that I reproduce NAVAS' original description:—

"Piceum, ultimis tribus abdominis segmentis testaceis. Caput prostomate longo, testaceo; antennis nigris, fortibus, 1-o articulo testaceo-fusco. Thorax inferne et lateraliter fulvus. Abdomen in ♂ processu dorsali 3-i segmenti arcuato, lumen inter ejus lasim et gibbam 4-i liberante, usque ad  $3\frac{1}{4}$  hujus segmenti pertingente; 4-o toto medio apicali dorso gibboso; 5-o brevi, 6-o conico, praecedente duplo saltem longiore, apicem versus sensim angustato; 7-o praecedente plus quam dimidio brevior, apice dilatato; 8-o praecedente vix longiore, apice dilatato et oblique truncato; 9-o oblongo, inflato, testaceo-rufo,



forcepe forti dentibus seu chelis interne sinuatis; furca longa, petiolo longo, marginibus lateralibus concavis, brachiis lanceolatis, fuscis, apice subobtusis, basi inter se spatium triangulare relinquentibus. Pedes fulvi, femoribus posticis rufescentibus, tarsorum articulis apice fusco annulatis. Alae angustae, in quarto apicali latae; membrana hyalina, vix nisi ad basim levissime fulvotincta; venis fusco-nigris; venulis juxta alae basim nigris, reliquis saltem externe albis; atomis papillaeformibus eodem situ et magnitudine ac in *ophthalmico* praeditis. Ala anterior ita fusco-notata: fascia apicali lata, postice ad marginem spatium circulare liberante; fascia stigmali, ad costam cum apical conjuncta, retrorsum furcata, tribus maculis linearibus, ante alae medium, quarum duae a costa, una inter et pone illas, a margine postico excurrente. Ala posterior similiter in medio apicali maculata, sed in fascia apicali spatium circulare in sinum rotundatum apertum; in medio basilari duae maculae distinctae, quarum prior costalis, ad medium altera marginalis posterior et in ♀ exiguae alia ad medium, post sectoris originem."

	♂	♀
"Long. corp. (a vertice)	16 mm.	12,5 mm.
" " d. anter.	15 "	15,5 " "
" " " poster.	13,5 "	13,8 " "

"*Patrie*: Tainan (Formose). Dans ma collection."

This can very probably be a varietal form of *P. communis* (see p. 341).

### 8. *Panorpa sauteri* Petersen.

*Taiwan-toge-shiriagemushi.*

*Panorpa sauteri* Petersen, Ent. Mitteil., Bd. i., No. 7, p. 197 (1912).

PETERSEN's type is the unique specimen as yet obtained of this species. His original description is:—

"Head, rostrum and palpi light brown; the apical joint of palpi with black tip. Antennae black; the first and second joint light brown. Pro-, meso- and metathorax light brown with a broad black median stripe on the dorsum. The black stripe begins at the ocelli, which are light brown like the head. First, second and third abdominal segment dorsally darkbrown, ventrally yellowish brown, fourth segment dorsally paler; the rest of segments dorsally and ventrally yellowish brown. The gonopoda (*appendage mihi*)



and the legs light brown. The process of the hind border of the third abdominal segment very long, almost as long as fourth, fifth and sixth segments together. Membrane of wings with a strong brownish yellow tinge; the nervures darker, especially the costa. Several dark spots and cross bands are to be found. Length 12.5 mm; fore wing 12 mm; hind wing 10.5 mm."

"One male, Type in Deutsches Entom. Museum, was captured by Sauter, VIII, 1909, at Koshun, Formosa."

Group II. (*Aulops* End.)

9. *Panorpa japonica* Thunberg.

*Shiraiagemushi.*

(Pl. XXXV., figs. 1,2,3,5, ♂; fig. 6, ♀; claw—text-fig. 2, e; appendage—Pl. XXX., fig. 14.)

*Panorpa japonica* Thunb., "Nov. Ins. Sp. Diss., iii., p. 67, fig. 9 (1784)"\*; Burmeister, Handb. d. Ent., Bd. ii., p. 957 (1839); Westwood, Trans. Ent. Soc. Lond., vol. iv., p. 188 (1846); Walker, List. Neurop. Coll. Brit. Mus., pt. ii., p. 461 (1853); M'Lach., Trans. Ent. Soc. Lond., 1878, p. 183; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 4.

*Panorpa sinanoensis* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 4, pl. i., fig. 7 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 5.

*Panorpa nipponensis* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 7, pl. i., fig. 3 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 5.

*Aulops japonica* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

*Aulops sinanoensis* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Aulops nipponensis* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body totally black; apex of rostrum piceous black; legs fuscous ochreous; claws highly curved, the apex far more prominently produced than the teeth; prominent teeth three.

\* The paper, which is not accessible to me, is indicated with " ."

Wings broad, hyaline, the apex round or elliptical; pterostigmatal fascia broad, the outer edge usually sinuate or furcate posteriorly beyond the middle; the furcate portion frequently forms a narrow branch and ends obliquely and outwardly on the posterior margin; occasionally the branch is isolated and remains as a marginal spot on the posterior margin; one or two irregular spots before the fascia; sometimes an irregular spot is still internally present; apex broadly black with the internal edge sinuate; sometimes markings are lightly coloured or partly fenestrated; longitudinal veins and some cross veins black; the remaining cross veins pale; first branch of radial sector with three or four branchlets.

In the male, the second to fifth abdominal segment cylindrical, slightly longer in progression; posterior margin of the third segment dorsally produced into a broad median lobe, which conceals a tubercle on the fourth segment; sixth and seventh segments each longer than the preceding segment, cylindrical, narrower in succession; eighth long, still narrower, conical, obliquely truncate at the posterior margin; cheliferous segment rather small, the chelae long and slender, piceous or testaceous; appendage Y-shaped, with the long stalk; each branch short and moderately broad; sometimes, however, it is rather narrow (form *niphonensis*) or slightly curved (form *sinanoensis*).

Length of body: ♂ 12–25 mm.; ♀ 15–25 mm.

Expanse: 32–42 mm.

Loc.: Shinano; Kiso; Gifu; Kiushiu (according to Prof. MATSUMURA).

Time of Appearance: May to August.

Subspecies *macrogaster* M'Lachlan.

*Ō-shiriagemushi*.

*Panorpa macrogaster* M'Lach., "Journ. Linn. Soc. Zool. ix., p. 257 (1867)";

Trans. Ent. Soc. Lond., 1878, p. 184; Miyake, Bull. Coll. Agr. Imp.

Univ. Tokyo, vol., viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 4.

*Aulops macrogaster* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910);

Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

Entire markings are traversed by a pale line between each of the veins so that they appear fenestrate; two to four blackish spots before the fascia.

Expanse: 30 mm. ; 34-41 mm. (after M'LACHLAN).

Loc. : Hakodate (according to M'LACHLAN).

Type form is still unknown to me. However as the characteristics of *macrogaster* are represented in various ways among the series of specimens of *japonica*, the present form should be considered rather as a subspecies of *japonica* than as a distinct species.

#### 10. *Panorpa pulchra* Miyake.

*Aja-shiriyagemushi.*

(Pl. XXXV., fig., 4, ♀; fig. 9, ♂; claw—text-fig. 2, f, g; fig. 7; appendage—Pl. XXX., fig. 17.)

*Panorpa pulchra* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 8, pl. i., fig. 4 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.

*Panorpa irregularis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 198, pl. xi., fig. 7 (1910).

*Aulops pulchra* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Aulops irregularis* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body deep black; antennae black; rostrum black or testaceous, with the palpi piceous; legs greyish fuscous or fuscous yellow, with fuscous tarsi; claws evenly curved, the apex strongly produced; prominent teeth, three or four, rather broad and obtusely pointed.

Wings broad, whitish, with the apex round or elliptical; pterostigmatal fascia very broad, with the inner edge rather sharply defined; the external edge usually furcate just beyond the middle, forming a narrow branch ending on the posterior margin, oblique in a direction contrary to that of the fascia, so that there is in most cases a vitreous space enclosed between the fascia and the branch; two rather irregular black spots before the fascia, of which the posterior one is larger and of quadrate form and usually united into an irregular narrow fascia; another series of two or three smaller spots before the last mentioned spots; these may also join with each other to form an irregular and incomplete fascia and frequently the costal spot of this inner series is connected with the posterior-marginal spot of the outer series, so that they represent the figure of a V; apex also very broadly black, its inner



margin sinuate; in some specimens certain parts of both the pterostigmatal fascia and apical dark space traversed by a pale line between each successive veins; longitudinal veins mostly black and especially very conspicuous in the basal half; cross veins mostly piceous in basal half and yellowish or testaceous in the space between the fascia and the apical dark portion; they are rarely colourless so that they represent fine white striae among the dark markings.

Abdomen blackish; in the male the posterior margin of the third dorsal segment is produced into a short median lobe just like that of *japonica*; sixth and seventh segments thick, cylindrical, truncate and equal in length; eighth slightly longer than the seventh, cylindrical; cheliferous segment short, the basal portion stout, the chelae brownish or piceous; appendage rather short, linear, black, and slightly broader than in *japonica*, with rather prominent ridges.

Length of body: ♂ 18 mm.; ♀ 14 mm.

Expanse: 32-36 mm.

Loc.: Goka-no-shō; Ōsumi; Mt. Hikosan, Kiushiu; Tosa.

Time of Appearance: May; July to August.

This species is allied to *japonica* and no striking difference can be found except in the wing-markings, though the form of the cheliferous appendage appears to be broader, much more divaricate and more acute than in *japonica*. I have therefore some grave doubts, as to whether they may not be amalgamated into one species. I have, however, for the present recognized them as two distinct species, because the differences of the same order as those found between them are used by recognized authorities in distinguishing other species of the same family, and moreover, the two species occur in detached places.

## 11. *Panorpa rectifasciata* Miyake.\*

*Obi-shiriyagemushi.*

(Pl. XXXV., fig. 7, ♂, fig. 8, ♀; claw—text-fig. 2, h; appendage—Pl. XXX., fig. 16.)

*Panorpa rectifasciata* (part) Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. vii., No. 1, p. 5, pl. i., fig. 10 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.

\* PETERSEN considers the species the same as *japonica*, from the similarity of their genitalia. If that is the case, I can make no objection to his opinion, though I have some specimens of *rectifasciata* which I think rather different from *japonica*.



*Aulops rectifasciata* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910);  
Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Campodotecnium* (?) *rectifasciata* Enderlein, Notes Leyd. Mus., vol. xxxiv.,  
p. 235 (1912).

Body totally black; palpi piceous; legs fuscous yellow; claws highly curved, with three prominent teeth.

Wings hyaline, the apex rounded; basal region usually tinged with ochreous, rarely the entire wings tinged with light ochreous; pterostigmatal fascia very broad, with both edges sharply defined; apex broadly black, with the inner edge slightly incurved; neither line nor spot anywhere present; longitudinal veins and most of cross veins fuscous; cross veins situated outwardly, whitish; first branch of radial sector with three or four branchlets.

Abdomen in the male from the second to fifth segment cylindrical, slightly longer in progression; the posterior margin of the third dorsal segment slightly produced (rather narrower than in *japonica*); sixth large, cylindrical; seventh cylindrical, narrower than the sixth, as long as the eighth; eighth very narrow, conical, obliquely truncate; cheliferous segment with slender chelae; appendage with long stalk; the branches rather short (slightly longer than in *japonica* and shorter than in *kluigi*), and widely distant from each other.

Length of body: ♂ 20 mm.; ♀ 17 mm.

Expanse: 35-40 mm.; 46 mm.

Loc.: Nikkō; Gifu; Towada; Kii; Aomori.

Time of Appearance: July, August.

This can be distinguished from other species by its broad pterostigmatal fascia sharply defined on both edges. However, the structural characters are to a great extent allied to *japonica*, and even now I have some doubts as to this being a truly distinct species. In the wing-markings it closely resembles certain form of *kluigi* so that I first erroneously confounded these two species. The figure accompanying the original description of *rectifasciata* was unfortunately drawn from such forms of *kluigi*, therefore the original description must be corrected as stated here, and the figure represented in a photograph in this paper looked upon as the true form. From *kluigi* the present species is distinguished by the greater broadness of the pterostigmatal fascia, larger size, shorter and much divaricate appendage, and light tinge of wings.

12. *Panorpa sachalinensis* Matsumura.*Karafuto-shiriyagemushi.*

*Panorpa sachalinensis* Mats., Journ. Coll. Agr. Tohoku Imp. Univ. Sapporo, vol. iv., pt. 1, p. 12, pl. i, fig. 9, 10 (1911).

I have not yet obtained a specimen of this species. The following is the reproduction of MATSUMURA's original description:—

“Pechschwarz. Rostrum an den Seiten und unten sowie auch Palpen bräunlich. Antennen schwarz, schwarz kurz dicht behaart. Pronotum in der Mitte mit 2 Querfurchen, wie das Mesonotum impunktiert, Scutellum hinten und Postscutellum bräunlich. Flügel hyalin, schwärzlich gefleckt beim ♂ ein wenig gelblich getrübt, Nerven dunkelbraun, Quernerven weisslichgelb, an der Spitze breit schwarz, am Zweidrittel des Flügels eine schiefgerichtete, in der Mitte eingeschnürte Querbinde, bei der Aussenseite dieser Binde am Hinterrande mit einem schwarzen Längsstriche, nahe in der Mitte mit einem den Vorrand nicht ganz erreichenden Querfleck oder mit 2 Fleckchen, noch ein anderes Fleckchen nahe am Costalrande zwischen diesem und der schiefen Querbinde; Hinterflügel gerade wie der Vorderflügel gefleckt, nur der Mittelfleck am Hinterrande in ein kleines Fleckchen reduciert und ein am Vorderrande liegendes Fleckchen fehlend; bei einem ♂ fehlen mittleren und innersten Querflecken. Beine blassgelblich, Coxen, Trochanter Tarsalsegmente an jeder Spitze und Klauenglieder dunkel; Klauen gelblich. Abdomen beim ♂ lang, am Hinterrande des 2ten Segmentes mit einer hakenförmig gekrümmten, an der Spitze abgerundeten Vorragung, welche mit einer zugespitzten konischen Vorragung des 3ten Segmentes zusammen stossend; Zange lang, an der Spitze gelblichbraun, nahe der Basis innen mit einer Vorragung, am letzten Segmente unten mit noch einem flachen zungenartigen Anhang, welcher die Gabelbasis der echten Zange bedeckend.”

“Länge: ♀ 13, ♂ 20 mm.”

“Flügel ♂ ♀ 15–17 mm.”

“Der Zeichnung und Form nach *P. macrogaster* M'L. etwas ähnlich.”

“Fundorte: Korsakoff, Mauka, Chipsani, Tonnaitcha, Galkinowraskoe und Todoroki, gesammelt in zahlreichen Exemplaren von Herren M. Oguma und B. Miyake.”

This species appears to me to be very closely allied to *P. amurensis* M'L. and *P. klugi* M'L.

### 13. *Panorpa bicornuta* M'Lachlan.

*Ô-lasami-shiriagemushi.*

(Pl. XXXVI., fig. 1, ♂, fig. 2, ♀, var.; claw—text-fig. 2, i; appendage—Pl. XXXI., fig. 16.)

*Panorpa bicornuta* M'Lach., Bull. Soc. Ent. Suiss., 1887, p. 403; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 4.

*Panorpa magnicauda* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 192, pl. xi., fig. 6 (1910).

*Aulops bicornuta* Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body black; eyes, antennae and palpi piceous; rostrum black; legs ochreous, with very slight fuscous tinge; extremity of each joint and terminal joint of tarsi fuscous, with the claws testaceous; dorsal body of claws evenly curved, the apex more or less produced over the teeth; prominent teeth four, very sharply pointed.

Wings hyaline, moderate, with the apex elliptical; pterostigmatal fascia rather narrow, oblique, somewhat attenuate towards the posterior margin; occasionally the fascia is reduced to a triangular costal spot; a small blackish apical patch (the patch occasionally encloses a small pale spot); basal half of the costal margin of fore and hind wings and the posterior margin of fore wing suffused with blackish; a very small blackish point at a place one-third from the base, rather nearing the posterior margin, frequently present; veins mostly piceous; first branch of radial sector with three or rarely four branchlets.

Abdomen black, very peculiar in shape; first segment just as in other species; second and third segments very short and almost equal in length; in the male, the third dorsal segment is produced in its middle into a short but broad lobe; fourth, fifth and sixth cylindrical, with testaceous pleural membranes; of the three segments the sixth is longest and the fourth shortest; seventh almost equal in length to the sixth, obliquely truncate anteriorly from dorsal side posteriorly to ventral side; the ventral apex of seventh segment



attenuate and pointed on each side so as to form two conspicuous spines (without a parallel among our species); eighth rather short, scarcely longer than sixth and seventh segments, conical and much narrower than the other segments, with the posterior margin obliquely truncate; cheliferous segment exceedingly large, with much elongate basal portion; chelae very short, slightly incurved, with testaceous apex; appendage very conspicuous, elongate, piceous, and extending over the middle of chelae; the distal end of the branches of appendage is overlapped, the left one up, so as to show an O-shaped structure; appendages of female black.

Length of body: ♂ 10–11 mm.; ♀ 12–13 mm.

Expanse: 31 mm.

Loc.: Goka-no-shō, Kiushiu; Mt. Gozu, Echigo.

Time of Appearance: May, June.

#### 14. *Panorpa hakusanensis*\* n. sp.

*Hakusan-shiriagemushi.*

(Pl. XXXVI., fig. 9, ♀; claw—text-fig. 2, j).

Body totally black; legs fuscous ochreous; claws evenly curved, with the apex produced over the teeth; prominent teeth four.

Wings hyaline, the basal half of costa margined with black; in the fore wing the posterior margin suffused from the base to the middle with fuscous; a spot somewhat triangular on the middle of costa and posterior margin; pterostigmatal fascia narrow and oblique, commencing at a large triangular patch which occupies the entire pterostigma; three short fasciae on the posterior margin between the pterostigmatal fascia and apex; apex slightly tinged with black; longitudinal veins as well as cross veins piceous; the first branch of radial sector with three branchlets.

Abdomen from the second to the fifth segment short, cylindrical, very slightly narrower in progression; sixth to the last very slender; appendages (female) black.

Length of body: ♀ 11 mm.

Expanse: 30 mm.

\* "Hakusan" is the name of the mountain in Kaga, where it was captured.



Type: A single female captured by Mr. MARUMO, on Mt. Hakusan (2600 m. high), Kaga, on Aug. 15, 1912.

15. *Panorpa pryeri* McLachlan.

*Pryer-shiriagemushi.*

(Pl. XXXVI., figs. 13, 14, 15, ♂; claw—text-fig. 2, k; appendage—Pl. XXX., fig. 12.)

*Panorpa pryeri* McLach., Trans. Ent. Soc. Lond., 1878, p. 185; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, p. 4.

*Aulops pryeri* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

Body black; basal joints of antennae fulvous; rostrum ochreous, slightly tinged with testaceous towards the extremity, with two very broad, deep black longitudinal striae; mouth-parts mostly testaceous; prothorax margined posteriorly with ochreous; meso- and meta-thorax with a narrow, or frequently broad, median, dorsal, ochreous line; scutelli and anterior margins of postscutelli ochreous; legs ochreous; claws evenly curved, the apex not produced over the teeth; very prominent four teeth present.

Wings rather broad, hyaline, dilated beyond the middle; apex acutely elliptical; a black fascia along the radius to one-third of the wing from the base, filling up the area between  $r_1$  and  $rs.$ ; a posteriorly elongate spot beyond the fascia; a narrow black fascia along  $cu_1$  to its extremity; posterior margin of fore wing from the base to  $cu_1$  irregularly margined with black; in the hind wing a small spot on the posterior margin at one-third from the base is sometimes present; pterostigmatal fascia is rather narrow and oblique, commencing at the pterostigma occupying its entire area and then attenuated towards the posterior margin; between this and the apex two small fasciae on the posterior margin and a rather prominent costal fascia are present; in some specimens, however, these are quite obsolete; apex margined with black; longitudinal veins towards the apex black; the rest and cross veins yellowish; first branch of radial sector usually with three branchlets.

Abdomen black; the pleural membranes (in dried specimen) testaceous; in

the male the second to fifth segment are rather stout, cylindrical; the posterior margin of the third dorsal segment produced into a very broad median lobe; sixth to eighth usually ochreous or with some black specks; sixth short conico-cylindrical, not elongate as in *japonica*; seventh narrow, slightly longer, with the extremity obliquely truncate; eighth cylindrical, narrower and very slightly longer than the preceding, with the posterior margin obliquely truncate; cheliferous segment testaceous; chelae rather short, usually crossing each other in a very oblique direction; appendage very large and broad, the lobes united in the middle; female with terminal segments gradually narrower; last two segments usually ochreous; appendages black.

Length of body: ♂ 11–15 mm.; ♀ 13–18 mm.

Expanse: 30–36 mm.

Loc.: Aomori; Usui-tôge; Gifu; Hibara, Iwashiro; Nikkô; Mt. Akagi; Mt. Nasu; Kiusiu (according to Prof. Matsumura.)

Time of Appearance: July to August.

Subspecies **major** Miyake.

(Pl. XXXVI., fig. 12, ♀.)

*Panorpa pryeri* var. *major* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 11, pl. i., fig. 8 (1908).

Size large; wing-markings strongly pronounced; apex of wing broadly black, caused by the coalescence of two or three striae.

Length of body: ♀ 16 mm.

Expanse: 40 mm.

Loc.: Nikkô.

Time of Appearance: June.

## 16. *Panorpa leucoptera* Uhler.

*Futasuji-shiriagemushi*.

(Pl. XXXVI., fig. 16, ♀, fig. 17, ♂; claw—text-fig. 2, 1; appendage—Pl. XXXI., fig. 13.)

*Panorpa leucoptera* Uhler, Proc. Ac. Nat. Sci. Philad., 1853, p. 31; M'Lach., Trans. Ent. Soc. Lond., 1878, p. 186; Miyake, Bull. Coll.

Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1 (1908); Navas, Rev. Russ. Ent., 1909, p. 4.

*Aulops leucoptera* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

Body ochreous; vertex of head shining black, rarely as in the body colour; eyes ochreous, testaceous, or black; ocelli pinkish; antennae testaceous, with the basal joints fulvous; rostrum ochreous with two slender piceous stripes; thorax frequently with black patches at the base of wings; legs ochreous; claws evenly curved, the apex somewhat produced over the teeth; prominent teeth four.

Wings hyaline, moderate, with the apex elliptical; markings blackish or fuscous; two spots at the areole of  $r_1$ . and  $rs$ ., of which one is at the origin and the other within it; pterostigmatal fascia very narrow and irregular, and commences at the posterior margin of the pterostigma, which is usually colourless and very rarely ochreous; the fascia is very broad between  $r_1$ . and  $rs$ . and abruptly narrowing between the first branch of  $rs$ . and  $r_4$ .; between the pterostigmatal fascia and the apex of wing two or three irregular patches are present; in certain specimens the markings are reduced to the mere pterostigmatal fascia, which runs only to the middle of wing; in certain cases, however, the markings are strongly pronounced; longitudinal veins mostly fuscous; veins forming the stalk of  $m$ . and  $cu_1$ ., anals and cross veins colourless; first branch of radial sector with three or four branchlets.

In the male the abdomen frequently bears black patches; second to seventh rather short, cylindrical, almost equal in length, of which the last segment is posteriorly truncate; third segment produced posteriorly into a broad median lobe; eighth somewhat longer and more slender than the preceding segment, truncate obliquely at the posterior margin; cheriferous segment large, chelae rather short, crossing each other; appendage very broad, each branch dilate towards middle and contacting each other along the body axis; abdomen of the female frequently suffused with testaceous; appendages piceous.

Length of body: ♂ 10-13 mm.; ♀ 12-14 mm.

Expanse: 29-32 mm.

Loc.: Sapporo; Hakodate; Moiwa; Jōzankei (all in Hokkaido).

Time of Appearance: August.



This species is very closely allied to *pryeri* and as both species vary so much beginners will experience difficulty in identifying the two species, but the two are distinct species and close studies will distinguish them. In *pryeri* the two striae on the rostrum are very broad and black, while in this species they are slender and piceous; pterostigmatal fascia commences in *pryeri* at the pterostigma, occupying the entire area of it, while in *leucoptera* it starts at the posterior margin of the pterostigma, the anterior part of this latter being usually unstained. Besides, *leucoptera* is usually smaller in size, and wing-markings rather less pronounced.

### 17. *Panorpa wormaldi* M'Lachlan.

*Kiashi-shiriagemushi.*

(Pl. XXXVI., fig. 18, ♂; claw—text-fig. 2, m; appendage—Pl. XXXI., fig. 14.)

*Panorpa wormaldi* M'Lach., Trans. Ent. Soc. Lond., 1878, p. 186;  
Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1  
(1908); Navas, Rev. Russ. Ent., 1909, p. 4.

*Aulops wormaldi* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body black; rostrum ochreous or fuscous ochreous; legs ochreous; claws rather highly curved; apex not produced over the teeth; prominent teeth four.

Wings rather broad beyond the middle, hyaline with the acutely elliptical apex; markings black, not deeply coloured; a streak along the costa from the base to the apex; an antero-posterior short streak at the end of subcosta; pterostigmatal fascia posteriorly forked at middle; posterior margin bordered with an irregular fascia from the base to the pterostigma, the inner half running along the margin and the outer half somewhat apart from the margin, with two marginal spots conjoining to it; next outwardly to the pterostigmatal fascia there is another linear streak between the anterior and posterior margins; apex narrowly margined; longitudinal veins except those of median and basal part black; the rest and cross veins colourless; membrane of wing somewhat iridescent; first branch of radial sector with three branchlets.

Abdomen black; the pleural membranes of the first to fifth segment yel-



lowish ochreous; third abdominal segment produced in its posterior margin into a short, broad median lobe; second to seventh segment cylindrical, almost equal in length and width; eighth very slightly longer than the preceding segment, cylindrical, and slightly narrower; cheliferous segment yellowish ochreous with basal portion above tinted with piceous; lateral portions stout, somewhat elongate; chelae very short, dilated towards its basal part; appendage rather larger, piceous black, broad, almost straight, somewhat dilated towards the apex, which is abruptly acute.

Length of body: ♂ 10 mm; ♀ 12 mm.

Expanse: 27 mm.

Loc.: Takaoyama near Hachiōji.

Time of Appearance: May.

Since the markings in all examples that I have captured are not deeply coloured the fact may be considered as one of the specific characters. As I could not obtain specimens from other localities it may be rather a rare species and Takaoyama is a definite locality.

### 18. *Panorpa striata* Miyake.

*Suji-shiriagemushi.*

(Pl. XXXVI, fig. 19, ♂; claw—text-fig. 2, s.)

*Panorpa striata* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii.,

No. 1, p. 5, pl. i., fig. 1 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.

*Aulops striata* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake,

Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body totally black, except the cheliferous segment, which is ochreous brown; legs fuscous yellow; claws rather highly curved, with the apex more or less produced over the teeth; prominent teeth three.

Wings with elliptical apex, the hind wing somewhat shorter than the fore wing; hyaline with black markings as follows:—subcosta with a streak from the base to the end; a small elongate spot connected with it transversely on the end of the subcosta; pterostigmatal fascia oblique, irregular, forked at its middle; two conjoined spots on the posterior margin internally from the pterostigmatal fascia; an irregular internally curved fascia from the anterior

margin to the posterior beyond the pterostigmatal fascia; between the two fasciae two elongate spots are present on the posterior margin; apex with a small dark portion, enclosing an elliptical spot of the ground colour in the fore wing; longitudinal veins brownish black; cross veins mostly whitish.

Abdomen black; in the male the posterior margin of the third segment produced into a short median lobe; sixth segment larger than the others; seventh and eighth segments not so long as the others (except the first), the eighth scarcely longer than the seventh; cheliferous segment stout, ochreous yellow; chelae very short, the basal part of appendage very broken (apex damaged in the type specimen), distal part of it being bent downward between the lateral portion of cheliferous segment, so that they represent a transverse ridge above.

Length of body: ♂ 13 mm.

Expanse: 27 mm.

Loc.: Nikkō (?).

A single male specimen (type) in the collection of the Imperial Central Agricultural Experiment Station, without date of capture or locality.

### 19. *Panorpa multifasciaria* Miyake.

*Hoso-madara-shiriagemushi.*

(Pl. XXXVI., fig. 20, ♀; claw—text-fig. 2, n.)

*Panorpa multifasciaria* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 196, pl. xi., fig. 5 (1910).

*Aulops multifasciaria* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body fuscous black; antennae piceous; rostrum black above, the lateral and under-sides with the palpi ochreous yellow; legs ochreous or fuscous yellow; claws evenly curved, the apex not produced over the teeth; prominent teeth three.

Wings hyaline, with rather acuminate apex; black or rarely fuscous markings as follows:—in some specimens there is a streak between the subcosta and radius from the base to the end of the former; in some specimens this streak is reduced to a very short one situated near the end of subcosta; and again in some specimens this streak is entirely absent; two

conjoined (rarely separate) elongate spots situated transversely just at the end of subcosta; pterostigmatal fascia irregular, oblique, dilated anteriorly at pterostigma and forked posteriorly in the middle of wing; posterior margin with an irregular fascia from the base to the end of the pterostigmatal fascia, the inner half running along the margin and the outer half, consisting of two conjoined spots, running a little anteriorly apart from the margin, so that two quadrate hyaline patches being enclosed between them; an irregular, sometimes discontinuous fascia running from the pterostigma (uniting anteriorly with the pterostigmatal fascia) to the posterior margin; another irregular fascia beyond the one just mentioned, from the costal to the posterior margin, forked in its lower half or broken into short streaks; a curved streak just before the apex; in some specimens, however, this is divided into many small spots; a rather indistinct short streak between each of the veins along the apex; longitudinal veins, except those of median and basal parts of wings, black; the rest and most of the cross veins black; wings somewhat iridescent; first branch of radial sector with four branchlets.

Abdomen in the male (unique specimen) rather short, fuscous, the ventral side and the cheliferous segment ochreous; posterior margin of the third dorsal segment produced into a short broad median lobe; sixth segment broadest of all the segments just as in the allied species *striata*; seventh equal in length to the sixth; cheliferous segment short but rather large, ochreous; lateral portion strongly rounded, chelae very short, but the basal two-thirds much dilated; appendage not satisfactorily recognizable on account of shrinkage; abdomen of the female tinged with fuscous all over; appendages piceous.

Length of body: ♂ 8 mm.; ♀ 13 mm.

Expanse: ♂ 28 mm.; ♀ 30-32 mm.

Loc.: Goka-no-shō, Kiushiu; Mt. Hikosan, Kiushiu; Gifu.

Time of Appearance: April, May.

This species is closely allied to *wormaldi* and *striata* in the wing-markings, though each species has some peculiar feature of its own. In all, the posteriorly forked pterostigmatal fascia, with the inwardly situated anterior and posterior marginal fasciae, is essentially alike, though there may be some slight differences between them. The outwardly situated second fascia is simple in the present species, while in *wormaldi* it is forked in its lower



half, and in *striata* its upper half is wanting, the lower forked portion alone running on the posterior margin; the third fascia of the present species is forked in its lower half, while that of *wormaldi* is straight and simple, and that of *striata* curved and simple, though inclined to join with the above stated marginal portion of the second fascia. Near the apex there is a short fascia in the three species; it is nearest to the apex and therefore shortest in *wormaldi*, *striata* comes next, and in the present species it is most removed from the apex and therefore longest. Besides, there is in this species, between each of the veins, a series of short apical striae which are never present in the other two species. Of course it is possible that the wing-markings of the present species may sometimes break up into pieces which are often hardly possible to trace. Besides, the wing of *wormaldi* is broader in proportion near the apex while that of the present species is only moderately so and therefore it looks slender.

## 20. *Panorpa takenouchii* Miyake.

*Hoshi-shiriagemushi.*

(Pl. XXXVI., fig. 7, ♂; fig. 10, ♂; claw—text-fig. 2, p, q; abdomen—Pl. XXIX., fig. 15.; appendage—Pl. XXX., fig. 3.)

*Panorpa takenouchii* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii.,

No. 1, p. 10, pl. i., fig. 5 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.

*Aulops takenouchii* Enderlein, Zool. Anz., Bd., xxxv., p. 390 (1910);

Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body ochreous in the male and piceous to black in the female; vertex of head with the eyes shining black; ocelli ochreous or pinkish; antennae piceous with the basal joint ochreous; rostrum ochreous edged laterally with a testaceous stripe; palpi testaceous; thorax in the male ochreous, with a fuscous patch at each side of scutum; in the female it is black, with the posterior margin of the prothorax and meso- and meta-scutellum (in one specimen meso-scutum as well) ochreous; legs ochreous; claws evenly curved, with the apex produced as long as the teeth; prominent teeth four.

Wings rather narrow, hyaline, with the apex rounded; in the male two black spots are present (frequently conjoining into a fascia) on the costa and the hind margin before the pterostigmatal fascia; pterostigmatal fascia narrow,



slightly curved inwardly; in a specimen it is separated into two spots, one on the costa and the other on the posterior margin; in the female there is another costal patch still internally near the base, which in a specimen is produced to the posterior margin; the next outer spots, corresponding to the innermost spots of the male, conjoined into an anteroposterior band, which also in the male rarely happens; pterostigmatal fascia angulated towards the base of wing in the middle and frequently conjoining with an internal spot on the posterior margin, giving the figure of a **Λ**; between the apex and the pterostigmatal fascia a spot is present on the posterior margin, always in the female and occasionally in the male; frequently the above stated fasciae isolated anteroposteriorly on the costa and posterior margin, as in the type form; apex tinged with black, obliquely and outwardly, in the form of an ellipse; longitudinal veins fuscous where they cross the markings; the rest ochreous; cross veins colourless; first branch of radial sector with three branchlets.

Abdomen with the second to the sixth segment cylindrical, almost equal in length; (in a male specimen, the second segment bears two conjoined black patches); in the male the posterior margin of the third dorsal segment produced into a very long process, extending over the cheliferous segment when it is bent up, and if abdominal segments are stretched straight it reaches the basal portion of the eighth segment; the process is rod-like, almost equal in thickness, slightly constricted near the base and somewhat dilated at the apex; it comes in contact ventrally with the middle posterior region of the fourth dorsal segment, the contacting portions of both bodies being hairy and slightly tuberculating (see Pl. XXIX., fig. 15); seventh and eighth obconical, larger and more slender than the preceding segment, truncate obliquely in the posterior margin; the basal portion of the cheliferous segment large; chelae rather small, crossing each other in an oblique direction; appendage very slender without stalk, the branches widely distant from each other and diverged posteriorly; between the chelae there is a pair of **V**-shaped chitinous harpes which are crossed with each other in the form of a **W**; in the female first to sixth black; the rest and pleural membranes ochreous; terminal segment slightly tinged with testaceous; appendages piceous.

Length of body: ♂ 10-12 mm; ♀ 12-15 mm.

Expanse: ♂ 27-29 mm.; ♀ 30-35 mm.

Loc.: Tosa; Mt. Iwawaki, Kii; Mt. Hikosan, Kiushiu; Formosa(?).

Time of appearance: May; July to August.

The male form has not hitherto been described. It is to a certain extent allied to *Panorpa santeri* of PETERSEN in having a long process on the third abdominal segment, but in that species the process does not surpass the sixth segment, while in the present species it extends over the eighth segment.

## 21. *Panorpa nikkoensis* Miyake.

*Nikkō-shirigemushi.*

(Pl. XXXVI., fig. 4, ♀; claw—text-fig. 2, r.)

*Panorpa nikkoensis* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyō, vol. viii., No. 1, p. 11, pl. i., fig. 2 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.

*Aulops nikkoensis* Enderlein, Zool. Anz., Bd. XXXV., p. 390 (1910);

Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body fuscous ochreous; head black; antennae with the basal joint ochreous; rostrum yellowish, with two brownish stripes; thorax and abdomen ochreous brown; meso- and meta-thorax ochreous; legs ochreous; claws evenly curved, with the apex slightly produced beyond the teeth; prominent teeth four.

Wings rather broad hyaline; apex elliptical; three small brownish black spots along the anterior margin, the outermost of which is in the pterostigma; a small spot on the posterior margin beyond the middle in the fore wing, and just at middle in the hind wing; a small spot just at the apex; longitudinal veins fuscous; cross veins white; first branch of radial sector with three branchlets.

Abdomen (in the female) fuscous ochreous, with the second to the fourth segment testaceous above; appendages piceous.

Length of body: ♀ 11 mm.

Expanse: 32 mm.

Loc.: Nikkō.

Time of Appearance: July, August.

The type (♀) was captured by Prof. SASAKI\* at Chuzenji, Nikkō, on Aug.

\* Erroneously I mentioned in the original description the capturer as Mr. MURATA.

28, 1887. The author obtained a female specimen at the same locality on July 20, 1900.

## 22. *Panorpa klugi* M 'Lachlan.

### *Bekko-shiriagemushi.*

(Pl. XXXV., fig. 10, ♂; claw—text-fig. 2, t; appendage—Pl. XXX., fig. 18.)

*Panorpa klugi* M 'Lach., "Journ. Linn. Soc. Zool., ix., p. 256 (1867)."

*Panorpa klugi* M 'Lach., Trans. Ent. Soc. Lond., 1878, p. 185; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 1. (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 4.

*Anlops klugi* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 91 (1911).

*Panorpa klugi* subsp. *nigra* (part) Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. iv., No. 2, p. 137 (1912).

Body testaceous, piceous, or black; legs fuscous or yellowish; claws stout, rather highly curved, with the apex hardly produced beyond the teeth; prominent teeth four.

Wings moderate, the apex rounded; tinged with yellowish or testaceous yellow; pterostigmatal fascia rather narrow, with sharply defined edges; one or two spots before the fascia and a spot on the posterior margin between the fascia and the apex frequently present; longitudinal veins testaceous or piceous, cross veins pale or testaceous; first branch of radial sector with three or four branchlets.

In the male the second to the fifth abdominal segment cylindrical, gradually shorter and longer; the dorsal posterior margin of the third abdominal segment produced into a short median lobe; sixth and seventh longer and narrower than the fifth; eighth slender, obconical, truncate obliquely at the posterior margin; cheliferous segment rather large; basal portion elongate; chelae slender, reddish testaceous, usually crossing each other at the apices; appendage with a long stalk, the branches rather long and slightly approximated towards apex; rarely they are rather short and divaricate.



Length of body: ♂ 12-15 mm.; ♀ 10-19 mm.

Expanse: 25-35 mm.

Loc.: Tokyo; Takaomaya; Nagano; Kiso; Gifu; Hakone; Harima; Mt. Gozu, Echigo; Okkai; Konsei-tôge; Akagi; Mt. Myogi; Nikkô; Hibara, Iwashiro; Aomori; Towada; Mt. Nasu; Shiobara; Kiushiu (according to Prof. Matsunuma)—possibly of general distribution in Japan.

Time of appearance: May to October.—In the vicinity of Tokyo it appears twice a year, first in May to June and second August to October.

In the vicinity of Tokyo the summer form (first brood), appearing in August, is ochreous yellow and the spring form (second brood), appearing in May, is blackish or piceous. In mountainous places, however, this is quite unfixed.

Subspecies *nipponensis* Navas.\*

*Maruhane-shiriagemushi*.

(Pl. XXXV., figs. 13, ♀, 14, ♂; Pl. XXXVII., figs. 11-34; appendage Pl. XXX., fig. 20).

*Panorpa nipponensis* Navas, Mem. R. Acad. Ci. Bar. vol. vi., No. 25, p. 20 (1908); Rev. Russ. Ent., 1909, No. 3, p. 7.

*Panorpa brachypennis* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, Vol. viii., No. 1, p. 9. pl. i., fig. 9 (1908).

*Aulops brachypennis* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910).

*Aulops nipponensis* Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

*Panorpa klugi* subspec. *nigra* (part) Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. iv., No. 2, p. 137 (1912).

*Campodotecnium(?) brachypennis* Enderlein, Notes Leyd. Mus., vol. xxxiv., p. 235 (1912).

*Campodotecnium(?) nipponensis* Enderlein, l.c.

Wings broad; pterostigmatal fascia irregular, outwardly with a short branch, which usually does not reach the posterior margin; apical dark

\* PETERSEN considers *nipponensis* and *klugi* different species. However, I am of another opinion; for this see the end of paragraph on next page.



portion inwardly curved in the middle; branches of appendage rather short, divaricate or parallel.

Length of body: ♂, ♀ 13-16 mm.

Expanse: 28-33 mm.

Loc.: Nikkō; Hakone; Tokyo.

Time of appearance: July to September; May (Tokyo).

This form appears to be a quite different species from *klugi*. However, my breeding experiments suggested to me that it should be considered as a varietal form of *klugi*. ENDERLEIN presumed that it may belong to his genus *Campodotecnium*, but it bears no character of that genus, as far as I could discover.

#### Subspecies *drouarti* Navas.

*Panorpa drouarti* Navas, Mem. R. Acad. Ci. Bar. vol. vi., No. 25, p. 21 (1908); Rev. Russ. Ent., 1909, No. 3, p. 7.

*Panorpa dyscola*\* Navas, Mem. R. Acad. Ci. Bar. vol. vi., No. 25, p. 22 (1908); Rev. Russ. Ent., 1909, No. 3, p. 5.

*Aulops drouarti* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Aulops dyscolu*\* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Wings with complete or incomplete oblique narrow fascia before the pterostigmatal fascia.

Length of body: ♂ 17-19.15† mm.; ♀ 33 mm.

Expanse: 28-33 mm.‡

Loc.: Tokyo; Kofu (according to NAVAS).

The typical form is still unknown to me. However, from the modes of variation represented in the collection of *klugi* before me, we can infer it cannot be any other than some varietal form of *klugi*.

#### Subspecies *maculata* n. subsp.

(Pl. XXXV., fig. 11, ♀; Pl. XXXVII., figs. 29-32).

\* PETERSEN thinks *dyscola* is the same as *pulchra* *mibi*. However, *pulchra* is the species which has hyaline wings almost without exception, while *dyscola* is reported to have wings "fusco levissime tinctae." For this reason I consider the latter to be a varietal form of *klugi*.

† I mention this after the original description of NAVAS. I cannot but think that it is an error, because we cannot recognize such an enormous size in *Panorpid*s.

‡ It is calculated approximately from the length of fore wing given by Navas.

Pterostigmatal fascia broad, with the edges irregular; one or two spots inwardly from the fascia present.

Length of body: ♂ 15 mm.; ♀ 11–15 mm.

Expanse: ♂ 27; ♀ 27–33 mm.

Type: Two male and female specimens in the collection of Agricultural College.

Loc.: Hakone; Kii.

Time of Appearance: August.

Subspecies *quadrimaculata* n. subsp.

(Pl. XXXV., fig. 12, ♀; Pl. XXXVII., figs. 33, 34.)

A small spot at middle of the anterior margin, connected with a large quadrate spot on the posterior margin; pterostigmatal fascia furcate; posterior margin near the base frequently suffused with black.

Length of body: ♀ 12 mm.; 14 mm.

Expanse: 26 mm.; 31 mm.

Type: Two female specimens in my collection.

Loc.: Hakone; Kii.

Time of Appearance: August.

A female specimen captured by Mr. YAMAZAKI at Hakone, Aug. 1910, and a female specimen captured by Mr. ISSHIKI on Mt. Iwawaki, Kii, 1910. These specimens represent a very interesting feature, showing us the kinship of *klugi* and *trizonata*.

### 23. *Panorpa trizonata* Miyake.

*Misuji-shiriagemushi*.

(Pl. XXXV., figs. 17, 18, ♂; claw—text-fig. 2, 0; abdomen and appendage—Pl. XXXIV., figs. 12a, 12b.)

*Panorpa tizonata* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 9, pl. i., fig. 11 (1908); Navas, Rev. Russ. Ent., 1909, p. 5.  
*Aulops trizonata* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Campodotecnium*(?) *trizonata* Enderlein, Notes Leyd. Mus., vol. xxxiv., p. 235 (1912).

Body black, testaceous or piceous; eyes blackish; ocelli pinkish; rostrum and antennae blackish to piceous; palpi piceous or testaceous; legs ochreous or fuscous yellow; claws highly curved, the apex slightly produced over the teeth; prominent teeth three, which are very acutely pointed.

Wings rather narrow, the apex rounded, yellow; pterostigmatal fascia very broad, furcate externally in the middle, forming an oblique branch ending on the posterior margin; another likewise broad fascia internal to the pterostigmatal fascia; between the two fasciae a costal spot is frequently present in both sexes; apex broadly black, with the inner edge slightly incurved; in the typical specimen the longitudinal veins ochreous, except the portions in the markings where they are fuscous; in many specimens the veins fuscous throughout; cross veins colourless or ochreous; first branch of radial sector with three branchlets.

Abdomen with the fourth to the eighth segment testaceous; posterior margin of the third dorsal segment produced into a short, broad, median lobe, which is usually broader but far shorter than that of *japonica*; fifth segment very slightly longer than the fourth, cylindrical; sixth long, stout, conico-cylindrical; seventh and eighth almost equal in length and much more slender than the preceding segment, so that the abdomen is abruptly attenuated from the seventh towards the end; cheliferous segment rather smaller and less stout than in *japonica*; chelae long and slender, the appendage longer than in *japonica* but shorter than in *ochraceopennis*, and curved as in the latter species.

Length of body: ♂, ♀ 18-22 mm.

Expanse: 27-32 mm.

Loc.: Mt. Iwawaki, Kii; Hakone; Takaoyama.

Time of Appearance: July to September.

It is remarkable that the male has usually a costal spot between the two fasciae, in the female this rarely occurs, and in both sexes the pterostigmatal fascia is usually furcate outwardly as in *japonica*, occasionally, however, in some female specimens it is sharply defined on both margins.



24. *Panorpa ochracea* Miyake.*Ki-hada-shiriagemushi.*

(Pl. XXXVI, fig. 11, ♂; claw—text-fig. 2, x; appendage—Pl. XXX, fig. 19.)

*Panorpa ochracea* Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo. vol. viii., No. 1, p. 3, pl. i, fig. 9 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 5.

*Aulops ochracea* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

*Campodotecnum* (?) *ochracea* Enderlein, Notes Leyd. Mus., vol. xxxiv., p. 235 (1912).

Body ochreous; vertex of head shining black, ocelli and eyes brown; antennae black; rostrum testaceous towards apex; prothorax black except the posterior margin; anterior half of the mesothorax blackish; a black line on the anterior margin of metathorax; legs brownish ochreous; claws highly curved with the apex produced over the teeth; prominent teeth three, broad.

Wings moderate; apex elliptical, tinged with ochreous, the basal half more deeply coloured; pterostigmatal fascia narrow; apex brownish black with slight internal sinuation; one or two small spots before the fascia in the fore wing and one or no spot in the hind wing; longitudinal veins testaceous and cross veins mostly colourless; first branch of radial sector forked in four branchlets.

Abdomen moderately long, brownish ochreous; a metallic black line on the first dorsal segment; two irregular metallic black patches on the second dorsal segment; the posterior margin of the third dorsal segment produced into a short broad median lobe; sixth and seventh thick, cylindrical, truncate and equal in length; eighth slightly longer than the seventh, cylindrical, truncate posteriorly; cheliferous segment short; basal portion less stout than in *japonica* and *klugi*, the chelae brownish ochreous with the tips brown, longer in proportion than in the preceding species; appendage ochreous brown, stalked, the branches divaricate and short as in *japonica* but more curved than in that species.



Length of body: ♂ 19 mm.

Expanse: 37 mm.

Loc.: Takaoyama; Yoshino; Mt. Iwawaki, Kii.

Time of Appearance: August.

This species is closely allied to *klugi* in the colouration of body and in the markings of wing, but is readily distinguished from the latter by difference in size (expanse in *klugi* 27–30 mm) and by the shorter appendage. In structural aspect it resembles *japonica*, but the colouration of body and wing, wing-markings and structure of the cheliferous segment distinctly separate the two species.

## 25. *Panorpa obscura* Miyake.

*Ko-obi-shiriagemushi.*

(Pl. XXXVI., fig. 22, ♂; claw—text-fig. 2, v; appendage—Pl. XXXI., fig. 17.)

*Panorpa obscura* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 195, pl. xi., fig. 5 (1910).

*Aulops obscura* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body blackish piceous; antennae and eyes testaceous; rostrum blackish piceous, with the palpi testaceous; legs yellowish; claws evenly curved; apex slightly produced over the teeth; prominent teeth three, with the basis very broad.

Wings moderate, slightly tinged with ochreous yellow; apex elliptical; pterostigmatal fascia rather broad but narrower than that of *japonica* and *rectijusciata*, the outer and inner edges rather wavy; apex also fuscous, with the inner edge slightly sinuous beyond the middle; no points or patches otherwise present; longitudinal and cross veins fuscous, of which the latter are somewhat lighter in colour; first branch of radial sector usually with four branchlets.

Abdomen blackish or blackish testaceous; in the male the posterior margin of the third dorsal segment is produced into a short broad median lobe; sixth segment stout, cylindrical; seventh slightly narrower and longer than the sixth; eighth slightly longer and much narrower than the seventh; cheliferous segment rather slender, the chelae ochreous, slender, the appendage rather long,

with a long stalk; branches of appendage divaricate towards their extremities, so as to show V-shaped structure.

Length of body: ♂ 16 mm.; ♀ 13 mm.

Expanse: 27–32 mm.

Loc.: Hibara, Iwashiro; Aomori.

Time of Appearance: July, August.

This species is allied to *rectifasciata* in its wing-markings, but as stated above, the ground colour of its wings is ochreous yellow, while that of *rectifasciata* is almost hyaline; the pterostigmatal fascia of the former is wavy and much narrower in proportion, while that of the latter is always straight, with very sharp edges and much broader than in the former. In this point it is also allied to certain forms of *klugi*. However, the structure of the cheliferous appendage readily separates the present species from the other two, because in this species each branch of the appendage is almost straight and divaricate distally, so as to show a V-form, while that of *rectifasciata* is much shorter and more curved and that of *klugi* is longer and approximated towards the extremity.

This species seems to be very rare, as it occurs only in a small restricted area.

## 26. *Panorpa ochraceopennis* Miyake.

*Kibane-shiriagemushi*.

(Pl. XXXV., fig. 15, ♂; claw—text-fig. 2, u; appendage—Pl. XXXI., fig. 18.)

*Panorpa ochraceopennis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 190, pl. xi., fig. 1 (1910).

*Aulops ochraceopennis* Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body black or blackish piceous; rostrum black; antennae and palpi fuscous to piceous; legs ochreous or fuscous ochreous; claws highly curved, the apex strongly produced; prominent teeth three, of which one or more teeth are usually flat and broad.

Wings moderate, tinged with fuscous ochreous; a little narrower compared

with that of *japonica*; apex elliptical; pterostigmatal fascia very broad, the outer edge of which is almost always sharply defined, though in a few cases it is slightly irregular, and the inner edge always fureate on its upper and lower portions; the upper branch arises just beyond the middle, running to the anterior margin, oblique in a direction contrary to that of the fascia; when it is produced to the anterior margin it encloses a round untinged space between the branch and the fascia; the lower branch runs always along the posterior margin and is usually more prominent than the former; both branches especially the lower one enlarge frequently into irregular patches, which when very pronounced may become continuous with each other; the fureation of the inner edges predominates usually in the fore wing, the inner edge in the hind wing in many examples being defined sharply like the outer edge; occasionally, however, it is fureate or the fureate portions reduced to marginal spots; apex also broadly blackish, with almost straight or slightly sinuated internal edge: longitudinal and cross veins of the basal half and the portion where they cross the markings mostly black; those of the space between the fascia and the apical portion yellowish; first branch of radial sector with four branchlets.

In the male, the posterior margin of the third abdominal segment is produced into a short, broad, median lobe, which is, however, shorter and broader than that of *japonica* and therefore less conspicuous than in the latter species; sixth, seventh and eighth segments almost equal in length, though they are very slightly longer in progression; sixth segment very stout and obconical, while seventh is very slender and cylindrical and much like the eighth, which is also very slender, so that the abdomen is abruptly attenuated from the seventh towards the extremity; cheliferous segment rather smaller and less stout than in *japonica*, chelae long, the appendage rather long and moderately curved as in *klugi* and the distal half bent downward between the two lateral portions.

Length of body: ♂ 11-18 mm.; ♀ 12-15 mm.

Expanse: 29-37 mm.

Loc.: Mt. Nasu; Hibara, Iwashiro; Mt. Yudono; Usui-tōge; Nikkō; Okkai, Kōtsuke.

Time of Appearance: July, August.



27. *Panorpa lewisi* M'Lachlan.*Tsumaguro-shirigemushi.*

(Pl. XXXV., fig. 16, ♂; claw—text-fig. 2, w; appendage—Pl. XXX., fig. 15.)

*Panorpa lewisi* M'Lach., Bull. Soc. Ent. Suisse, 1887, p. 402; Bull. Coll. Agr. Imp. Univ. Tokyo, vol. iii., No. 1, p. 1 (1908); Navás, Rev. Russ. Ent., 1909, p. 4.

*Panorpa chuzenjiensis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 20 (1910).

*Aulops lewisi* Enderlein, Zool. Anz., Bd. xxxv., p. 390 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body black; antennae and palpi blackish piceous; legs fuscous ochreous, with the coxa and trochanter black; claws highly curved, the apex strongly produced over the teeth; prominent teeth three, apices not so sharply pointed.

Wings moderate, tinged with fuscous ochreous; slightly narrower compared with that of *japonica*; apex elliptical; a small blackish costal patch somewhat triangular in the fore wing and semi-elliptical in the hind wing, just at the commencement of the pterostigma, occupying about one third of the latter; apex tinged with blackish (not so broad as in *japonica*), with almost straight internal edge running obliquely posteriorly and outwardly; no other patch or fascia present; pterostigma somewhat opaque; longitudinal veins black; cross veins black except in the apical portion where they are white; first branch of radial sector with three or four branchlets.

Abdomen black; in the male the posterior margin of the third dorsal segment is produced into a short but very broad median lobe (broader than that of *japonica*); sixth, seventh and eighth segments cylindrical, almost equal in length and much more slender than in *japonica*; chelae long; appendage rather long and moderately curved and the distal half bent downward between the two lateral portions.

Length of body: ♂ 19–20 mm.; ♀ 12 mm.

Expanse: 38 mm.

Loc.: Chuzenji, Nikkō; Okkai, Kōtsuke.

Time of Appearance: July.



Genus *Panorpodes* McLachlan (1875).

Antennae long; rostrum rather bluntly ended. Wings broad, marked or unmarked; subcosta usually connected with the costa by two cross veins. Legs moderately long; ventrally without teeth. Abdomen cylindrical in the male and conical in the female; first abdominal segment modified. Male with the forceps at the extremity. Habits unknown.

*Key to the species found in Japan.*

- A. Wings unmarked. . . . . *paradoxa*.
- B. Wings marked.
  - a. Apex of wings margined with fuscous.
    - a<sup>1</sup>. With no other markings. . . . . *naevia*.
    - b<sup>1</sup>. With Y-shaped marking in the fore or in both wings.
      - . . . . . *decorata*.
  - b. Apex of wings not margined with fuscous. . . . . *notata*.

28. *Panorpodes paradoxa* McLachlan.*Sukashi-shiriagemushi-modoki.*

(Pl. XXXVII., fig. 1, ♂; claw—text-fig. 2, y; appendage—Pl. XXXI., figs. 8 a, 8 b.)

*Panorpodes paradoxa* McLach., Trans. Ent. Soc. Lond., 1875, p. 189; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2 (1908); Navas, Rev. Russ. Ent., 1909, No. 3, p. 5; Enderlein, Zool. Anz., Bd. xxxv., p. 393 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

Body testaceous or ochreous; ocellar triangle usually shining black; ocelli ochreous; eyes shining black; antennae and palpi testaceous; legs ochreous.

Wings rather broad, apex acutely elliptical, ochreous, without markings; pterostigmal region usually of a deeper shade than the ground colour, opaque and finely granulose; longitudinal veins fuscous; cross veins almost colourless; first branch of radial sector with three branchlets.

Abdomen in the male rather short, the second to eighth segment cylindric-

ical, short, and almost equal in length; the eighth obliquely truncate on the posterior margin; cheliferous segment exceedingly large, the chelae small, crossing each other in a very oblique direction; appendage large, with a long stalk and two stout lateral branches, which are curved and approximated very closely at their apices, where there is a small triangular black process with some dentation on each inner edge; in the female the terminal segments of abdomen are telescoped inward so that the abdomen looks very short and conical, whereas in reality it is far longer than in *Panorpa* and cylindrical.

Length of body: ♂ 10–13 mm.; ♀ 11–14 mm.

Expanse: 30–33 mm.

Loc.: Nikkō; Takaoyama; Goka-no-shō; Gifu; Mt. Gozu, Echigo; Akita, Ugo.

Time of Appearance: May; July (Nikkō).

This insect seems to appear once a year, in plains in May and in mountainous places in midsummer.

Subspecies *stigmatica* n. subspec.

(Pl. XXXVII., fig. 2, ♂.)

Head testaceous; thorax mostly piceous; abdomen piceous or piceous black; longitudinal veins deeply fuscous; cross veins hyaline; stigmatal region tinged with fuscous.

Length of body: ♀ 12 mm.; 13 mm.

Expanse: 32 mm.; 35 mm.

Type: Two female specimens, one captured by Mr. HATAKEYAMA on Mt. Gozu, Echigo, on June 9, 1910, and the other by the author at Nikkō, June 22, 1911.

## 29. *Panorpodes naevia* Navas.

*Tsumaguro-shiriagemushi-modoki.*

(Pl. XXXVII., fig. 3, ♀.)

*Panorpodes naevia* Navas, Rev. Russ. Ent., 1909, No. 3, p. 1; Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

*Panorpodes apicalis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 203, pl. xi., fig. 4 (1910).

Body totally ochreous; antennae and palpi testaceous; eyes ochreous; ocellar triangle fuscous; legs yellow.

Wings pale ochreous with the apex rounded; towards the apex they are much broader in proportion than in *paradoxa*; apices are margined with fuscous; pterostigmatal region uniformly coloured as the rest of wing and not opaque as in *paradoxa*; first branch of radial sector with three branchlets.

Length of body: ♀ 11 mm.

Expanse: 33 mm.

Loc.: Takaoyama; Mt. Gozu, Echigo.

Time of Appearance: May.

This species is allied to a certain extent to *paradoxa*, but differs by its lighter coloured and relatively broader wing with rounded apex, and uniformly coloured pterostigma, *paradoxa* having deeply coloured wings, with slightly narrowed elliptical apex and opaque testaceous pterostigma.

Male unknown.

### 30. *Panorpodes decorata* M'Lachlan.

*Matamon-shiriagemushi-modoki.*

(Pl. XXXVII., fig. 7, ♀.)

*Panorpodes decorata* M'Lach., Bull. Soc. Ent. Suisse, 1887, p. 405; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2; Navas, Rev. Russ. Ent., 1909, p. 5; Miyake, Entomologist, vol. xlv., No. 574, p. 92.

Body mostly fuscous; vertex of head, ocellar triangle and eyes shining black; antennae and palpi piceous; basal joint of antennae fulvous; rostrum ochreous, anteriorly with a broad piceous band; posterior margin of prothorax, dorsal median part of scutum, scutellum, and postscutellum of meso- and meta-thorax ochreous; the rest piceous; legs ochreous.

Wings tinged with ochreous like *paradoxa* but more dilated outwardly than in that species; apex usually more acute than in *paradoxa*; pterostigmatal fascia fuscous, anteriorly forked in the middle, showing a Y-figure which encloses a round spot of the ground colour between the two branches; a short streak or spot between  $cu_1$  and  $cu_2$ ; apex bordered with piceous; between the

pterostigmatal fascia and the apex of wing one or two irregular fasciae are present, of which the inner one occasionally unites anteriorly with the outer forked branch of the pterostigmatal fascia at the pterostigma; longitudinal veins fuscous; cross veins colourless; first branch of radial sector with three branchlets.

Abdomen (in the female) conical, mostly fuscous or piceous; terminal segments ochreous.

Length of body: ♀ 14 mm.

Expanse: 30-36 mm.

Loc.: Nikkō; Mt. Gozu, Echigo; Betsuzan, Kaga.

Time of Appearance: June; August.

Male unknown.

Subspecies *singularis* Miyake.

*Kasuri-shiriagemushi-modoki*.

(Pl. XXXVII., fig. 4, ♀.)

*Panorpodes singularis* Miyake, Journ. Coll. Agr. Imp. Univ. Tokyo, vol. ii., No. 3, p. 204, pl. xi., fig. 9 (1910); Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body testaceous; the Y-shaped pterostigmatal fascia of fore wing reduced into three spots, two anteriorly and one posteriorly placed; hind wing has only one costal spot instead of the pterostigmatal fascia.

Length of body: ♀ 13 mm.

Expanse: 32 mm.

Loc.: Hibara, Iwashiro; Mt. Gozu, Echigo.

Time of Appearance: July.

Male unknown.

Subspecies *limbata* (Navas).

*Maye-matamon-shiriagemushi-modoki*.

(Pl. XXXVII., fig. 5, ♀.)

*Panorpa limbata* Navas, Rev. Russ. Ent., 1909, No. 3, p. 2.

*Panorpodes limbata* Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).



Body piceous; the Y-shaped pterostigmatal fascia present only in the fore wing; in the hind wing it is reduced into four spots, two anterior on the costa, one in the middle and the other one on the posterior margin.

Length of body: ♀ 11 mm; 13 mm.

Expanse: 32 mm.

Loc.: Chūzenji, Nikkō.

Time of Appearance: July.

Male unknown.

Subspecies *confusa* n. subsp.

*Midare-shiriagemushi-modoki*.

(Pl. XXXVII., fig. 6, ♀; Pl. XXXIV., fig. 11, ♀.)

Body fuscous yellow with slight brown tinge; head testaceous; rostrum with the palpi and antennae testaceous; legs fuscous yellow.

Wings pale yellowish, with the apex rounded; pterostigmatal region entirely yellowish fuscous; apex margined with fuscous; in the fore wing there is a rather irregular fascia present, obliquely from the anterior to the posterior margin, outwardly to the pterostigmatal fascia; pterostigmatal fascia arises at the internal end of the pterostigmatal patch and terminates at the posterior margin, which is connected with the first mentioned fascia by the stigmatal patch; another still internally placed fascia across the wing, which is connected with the last mentioned fascia by a bar on the radius; a small fuscous spot at  $cu_1$  near the posterior margin; in the hind wing the markings are rather obscure; the spot at  $cu_1$  absent; longitudinal veins partly fuscous and partly testaceous; cross veins pale testaceous.

Length of body: ♀ 14 mm.

Expanse: 32 mm.

Type: A single female specimen in my collection, captured by Mr. HATAKEYAMA on Mt. Gozu, Echigo, June 9, 1910.

This form is rather different from either *decorata* or *limbata*, and at first I considered it as a new species. After careful consideration, however, I have come to the conclusion that it is better to regard it as a varietal form of *decorata*.

As all the known specimens of this species as well as its subspecies are females, I have some doubts as to its specific standing; it is possible that it may have to be sunk into some other species, such as *decorata*, though from the latter species it is distinguished by the more acute apex of the wing.

### 31. *Panorpodes notata* Navas.

*Madara-shiriagemushi-modoki.*

*Panorpodes notata* Navas, Rev. Russ. Ent., 1909, No. 3, p. 3; Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

I have not yet obtained a specimen of this species. The following is the reproduction of the original description:—

“Ferruginea.”

“Caput inter ocellos fuscum; oculis nigris, ellipticis, constrictis; antennis fusco-ferrugineis; labro profunde exciso; palpis ferrugineis, articulorum aliquot apices fusco.”

“Thorax unicolor, ferrugineus, subnitens.

“Abdomen ferrugineum, basim versus fuscescens, apicem versus pallidius.

“Pedes ferruginei, tarsis apice obscurioribus.”

“Alae membrana fulvo tincta, venis ferrugineo-fuscis, venulis fulvis.”

“Ala anterior vena subcostali ante apicem convexa, apice stigma attingente; membrana maculis fusco-ferrugineis: fascia vaga ultra medium alae interrupta, alia stigmali externe convexa, retrorsum incompleta, alia anteapicali nebulosa; praeterea duabus tribusve aliis in medio basilari.”

“Ala posterior vena subcostali cum costa longe ante stigma confluyente; membrana parum maculata, praeter maculam stigmalem et marginalem posteriorem reliquis obsoletis.”

“Mas mihi ignotus.”

“Longit. corp. 12 mm.”

“—— alae anter. 14 mm.”

“—— —— poster. 12.5 mm.”

“Un échantillon chétif a les dimensions 10,-8,4-7,5 mm. respectivement.”

“Patrie: Nippon moyen, environs de Tokio. J. Harmand. 1906.”

Genus *Leptopanorpa* M'Lachlan (1875).

The genus as well as its species are known to me by the descriptions only; the following are the reproductions of their original descriptions given by M'LACHLAN:—

“Differs from *Panorpa* by the extreme slenderness of all its parts; the wings very narrow; the rostrum exceedingly long; the three terminal segments of the ♂ abdomen immensely long, and almost thread-like, the cheliferous segment being provided with a very long footstalk; the basal (unmodified) segments long (not transverse as in *Panorpa*).”

*Key to the species found in Japan.*

- A. Pterostigmatal fascia present. . . . . *ritsemæ*.  
 B. Pterostigmatal fascia absent. . . . . *sieboldi*.

32. *Leptopanorpa ritsemæ* M'Lachlan.*Hoso-shiriagemushi.*

*Leptopanorpa ritsemæ* M'Lach., Trans. Ent. Soc. Lond., 1875, p. 187;  
 Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2;  
 Navas, Rev. Russ. Ent., 1909, No. 3, p. 5; Enderlein, Zool. Anz.,  
 Bd. xxxv., p. 393 (1910); Miyake, Entomologist, vol. xlv., No. 574,  
 p. 92 (1911).

“Testaceous, the head blackish (excepting posteriorly), and with a black median line along the thorax (in the ♀ the head and thorax are nearly wholly blackish above). Legs yellowish; wings with a slight testaceous tinge, and with fuscous veins; there is a very narrow pale fuscous fascia beyond the middle, expanding on the costa, where it forms the inner side of the pterostigma (in the posterior wings this fascia is abbreviated or interrupted), and (in the ♀) two or three small basal spots; posterior edge of the 5th abdominal segment in the ♂ blackish; terminal segments yellowish; 6th and 7th segments each nearly as long as all the basal segments united; the apical portion gradually incrassate; footstalk of the cheliferous segment scarcely shorter and of the same form; its apex considerably dilated,

so that the basal portion (before the claws) is somewhat pyriform; claws long, strongly curved and crossing; appendages very long and slender, extending beyond the base of claws. (In the ♀ the terminal segments of the abdomen are very slender.)"

"Total length of body of ♂ about 25 mm.; expanse 25 mm."

"One pair (♂, ♀) in the Leyden Museum; captured by Von Siebold."

### 33. *Leptopanorpa sieboldi* M'Lachlan.

*Tsumaguro-hoso-shiriagemushi.*

*Leptopanorpa sieboldi* M'Lach., Trans. Ent. Soc. Lond., 1875, p. 188; Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2; Navas, Rev. Russ. Ent., 1909, No. 3, p. 5; Enderlein, Zool. Anz., Bd. xxxv., p. 393 (1910); Miyake, Entomologist, vol. xlv., No. 574, p. 92 (1911).

"Head deep black, pale posteriorly; rostrum piceous, with pale sides. Thorax piceous in front, testaceous posteriorly, wholly yellow beneath. Abdomen fuscous. Legs yellow. Wings with a slight greyish tinge, and with fuscous veins; the only marking is a rather broad pale fuliginous apical space, straight internally (♀)."

"Expanse 24 mm."

"Two females in the Leyden Museum; captured by Von Siebold."

"An approach towards the abdominal formation in the ♂ of *Leptopanorpa* is to be found in *P. nematogaster*, M'Lach., from Java (perhaps also in *P. Charpentieri*, Burm.), but in it the cheliferous terminal segment is sessile. The genus very clearly shows that the abdomen in the *Panorpidæ* has nine segments; for the 1st segment, ordinarily confused with the hinder portion of the metathorax, is here very long."

#### SUBFAMILY II. BITTACINÆ.

*Cu.*, partly fused with the media both in fore and hind wings; claws unpaired.



Genus *Bittacus* Latreille (1807).*Diplostigma* Navas (1908).

Antennae short; rostrum sharply pointed. Wings dilate, usually without conspicuous markings; subcosta usually connected with the costa by a single cross vein. Legs very slender; claws ventrally without teeth. Abdomen cylindrical; first segment modified. Male without forceps at the extremity. Adult in repose hangs down vertically from a branch of tree and preys on living insects.

*Key to the species found in Japan.*

- A. Body entirely piceous (excepting legs and pleural membranes). . . . .
- . . . . . *takaoensis* n. sp.
- B. Body fulvous or testaceous, frequently with some fuscous patches.
- a. Apex of wings margined with fuscous. . . . . *marginatus* n. sp.
- b. Apex of wings not margined with fuscous.
- a<sup>1</sup>. Hind femur of male with conspicuous black hairs; cross veins not margined with fuscous. . . . . *nipponicus*.
- b<sup>1</sup>. Hind femur of male without conspicuous black hairs; cross veins margined with fuscous.
- a<sup>2</sup>. Wings with four fuscous spots at the origins of some veins.
- . . . . . *quaternipunctatus*.
- b<sup>2</sup>. Wings without fuscous spots.
- a<sup>3</sup>. Appendage of male with the entire margin . . *laevipes*.
- b<sup>3</sup>. Appendage of male with the margin notched. . *sinensis*.

34. *Bittacus nipponicus* Navas.*Hime-kagambo-modoki*.

(Pl. XXXIII., fig. 7,—wing; appendage—Pl. XXXI., figs. 3; 4.)

*Bittacus sinensis* (part) M'Lach., Bull. Soc. Ent. Suiss., 1887, p. 406;  
Matsumura, Senchu-zukai (Thousand Insects of Japan), vol. i., p.  
165, pl. xi., fig. 5 (1904); Miyake, Bull. Coll. Agr. Imp. Univ.

Tokyo, vol. viii., No. 1, p. 2 (1908); Entomologist, vol. xliv., No. 574, p. 92 (1911).

*Bittacus nipponicus* Navas, Rev. Russ. Ent., 1909, No. 3, p. 3; Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body fuscous ochreous; ocellar triangle black; ocelli bright fulvous; eyes black; antennae fuscous with ochreous basal segment; apical half of rostrum piceous, margined with ochreous; palpi fuscous with testaceous, or frequently ochreous, apex; legs fuscous ochreous, testaceous towards the terminal joints; under side of the posterior femur in the male armed with black conspicuous hairs.

Wings rather broad, fuscous ochreous; longitudinal and cross veins fuscous; rarely outer cross veins and outer margin bordered with fuscous; pterostigma opaque, ochreous, connected with the first branch of radial sector by two cross veins.

In the male the second to the fifth abdominal segment long, cylindrical, the sixth shorter, the seventh still shorter, posteriorly dilate; dorsal appendage with a deep notch in each lobe.

Length of body: ♂, ♀ 15-16 mm.

Expanse: 38-40 mm.

Loc.: Inokashira near Tokyo; Tokyo.

Time of Appearance: July.

This is the common species in the vicinity of Tokyo. It usually occurs in abundance in a certain fixed spot and is not generally distributed. The locality where it occurs is also inhabited by a number of Tipulids which very closely resemble it. FELT mentions the same fact in his work on the American species. So that it can be supposed that the weak *Tipula* imitates the ferocious *Bittacus*.

Though this species is allied to a certain extent to *sinensis*, the form of appendage and femur of male well distinguish it. NAVAS did not restrict the characteristic femur to one sex, but it is limited only to the male. It is very strange that he did not put this species into his genus *Diplostigma*, as it bears the exact characters of that genus; he himself has mentioned the species side by side to *sinensis* in his list of the Panorpidae, the former as *Bittacus* and the latter as *Diplostigma*.

Cross veins are not usually bordered with fuscous except in some rare cases, and even then they are bordered far narrower than in *sinensis*. It is almost clear that M'LACHLAN included this species into his *sinensis*. However, in many respects it cannot be considered as the same species, nor the varietal form of it; it must be considered as a different species.

### 35. *Bittacus laevipes* Navas.

*Yeguri-kagambo-modoki*.

(Pl. XXXVII., fig. 9, ♀; wing—Pl. XXXIII., fig. 9.)

*Bittacus sinensis* (part) M'Lach., Bull. Soc. Ent. Suiss., 1887, p. 406.

*Bittacus laevipes* Navas, Rev. Russ. Ent., No. 3, p. 4 (1909); Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

Body brownish ochreous; head with the rostrum ochreous, testaceous, or piceous; ocelli pinkish or testaceous, or frequently black; eyes blackish or testaceous; antennae testaceous, with the ochreous basal joint, or entirely piceous; palpi testaceous; thorax with brownish suffusion or with irregular patches; legs slender, ochreous, the terminal joints testaceous.

Wings fuscous ochreous, with the apex acutely elliptical; pterostigma opaque, greyish ochreous, posteriorly connected with the radial branch by two cross veins; apical region slightly dusted with fuscous; longitudinal and cross veins fuscous; the latter margined with fuscous.

Abdominal segments from the second to the fifth cylindrical, rather long; sixth shorter, seventh still shorter; in the male the terminal segment is dilated towards extremity; dorsal bilobed appendage large; each lobe semi-elliptical, with the margin entire; abdomen in the female clavate, with the appendages ochreous; in both sexes the terminal segment more or less tinged with testaceous.

Length of body: ♂, ♀ 16–18 mm.

Expanse: 43–47 mm.

Loc.: Mt. Iwawaki, Kii; Kiso; Mt. Kōya, Kii.

Time of Appearance: July to August.

This species, together with some other occurring in Japan was first referred to by M'Lachlan as *Bittacus sinensis*, adding however—"Ayant sous les yeux



une quantité assez considérable des *Bittacus* du Japon, je ne suis pas certain que tous les individus appartiennent à une seule espèce, malgré leur ressemblance générale. En regardant les appendices du mâle je trouve que chez les **sinensis** de la Chine septentrionale, les appendices supérieurs ont une excision au bout. La plupart des individus du Japon sont également formés; mais il y en a d'autres chez lesquels les appendices ont l'air d'être entiers; et chez un seul mâle les appendices me semblent autrement conformés, plus étroits, et avec l'excision beaucoup plus profonde, etc. Il faut attendre encore de nouvelles recherches avant de considérer tous les individus comme étant d'une seule espèce."\*

The present species undoubtedly corresponds to the second form stated above, which has the margin of the appendage entire, and to which NAVAS has given the present new name. Nevertheless as in the original description of *Bittacus sinensis* the form of the appendage was not mentioned, I am entirely uncertain which of the above stated forms should be considered as the typical *sinensis*, as long as the type specimen is not examined. Accordingly I am still more uncertain whether the present species is a new species or not. Accepting NAVAS' proposal I recognise the present form as a different species from the true *sinensis*, which is said to have the excision on the dorsal appendage of the male. I have not yet seen the latter species in Japan.

The present species possesses the characters of NAVAS' genus *Diplostigma*, though he did not place it into that genus.

### 36. *Bittacus sinensis* Walker.

#### *Kagambo-modoki.*

*Bittacus sinensis* Walk., List. Neur. Ins. B. M., pt. ii., p. 469 (1853); (part) McLach., Bull. Soc. Ent. Suiss., 1887, p. 406; (part?) Matsumura, Senchu-zukai, vol. 1, p. 165, pl. xi., fig. 5 (1904); (part) Miyake, Bull. Coll. Agr. Imp. Univ. Tokyo, vol. viii., No. 1, p. 2 (1908).

*Diplostigma sinense* Navas, Rev. Russ. Ent., 1909, No. 3, p. 5; Miyake, Entomologist, vol. xliv., No. 574, p. 92 (1911).

\* Bull. Soc. Ent. Suiss., 1887, p. 406.



Following M'LACHLAN's conception of the species I was formerly referring all our *Bittacus* to the present species. As can be seen below, the original description being very simple, I could not make an exact study on the specific characters without consulting the type specimen. The following is the description:—

"Ferrugineus; antennae pubescentes; abdomen piceo vittatum; pedes fulvi, graciles; alae flavae, stigmatæ fulvo, venis transversis fusco-nebulosis."

"Ferruginous: antennae pubescent; abdomen with a pitchy stripe: legs tawny, slender: wings yellow; stigma tawny; transverse veins clouded with brown. Length of the body 7 lines; of the wings 20 lines."

"a. Shanghae, China. From Mr. Fortune's collection."

As was mentioned under the description of *Bittacus laevipes*, M'LACHLAN himself noticed various differences in the appendages of the males in the forms that he included under *Bittacus sinensis* and had some doubts in referring them all to that single species. NAVAS afterwards proposed a new name for the form that has the appendage with the entire margin. If we approve his statement, the true *sinensis* must be the form that has the appendage with the sinuated margin. And in many respects it can be presumed that it may differ on many points from *Bittacus nipponicus*, so that the present species should be the form very closely allied to *Bittacus laevipes* and only differing in the form of appendage. Such forms, however, I have not yet seen in Japan. Whether such forms should be true *sinensis* or not, or whether they are found in Japan or not, is, at present, quite undeterminable.

### 37. *Bittacus quaternipunctatus* Enderlein.

*Hoshi-kagambo-modoki.*

(Pl. XXXVII., fig. 10, ♀; wing—Pl. XXXIII., fig. 6.)

*Bittacus quaternipunctatus* Enderlein, Zool. Anz., Bd. xxxv., p. 397 (1910).

Body ochreous or rarely testaceo-ochreous; ocellar triangle black or testaceous; eyes brownish or testaceous; antennae entirely testaceous or the basal segment ochreous.

Wings brightly ochreous; pterostigma fuscous ochreous, opaque, connected by two cross veins with the radial branch; four small rounded piceous spots

present: one each on the cross vein between *sc.* and  $r_1$ , on the origins of  $r_2$  and  $r_1$ , and on the differentiating point of *m.* from the common stalk of it and  $cu_1$ ; in the female the first mentioned spot obsolete; veins testaceous or ochreo-testaceous; cross veins in outer half of wing narrowly bordered with fuscous.

Abdomen like that of *laevipes*; the lobe of the dorsal appendage of the male with a short narrow notch.

Length of body: ♂ 17 mm.; ♀ 18–19 mm.

Expanse: ♂ 42 mm.; ♀ 46 mm.

Loc.: Gifu; Kii.

Time of Appearance: July, August.

Distribution: Japan; Corea.

ENDERLEIN's type is a female from Corea; the species is very closely allied to *laevipes*, but can be distinguished from the latter species by the presence of four spots, the form of appendage and brighter colouration of body and wing.

### 38. *Bittacus takaoensis*\* n. sp.

*Kuro-kagambo-modoki.*

(Pl. XXXIII., fig. 8,—wing.)

Body totally black,† except the pleural membranes of abdomen; antennae and palpi fuscous yellow; apex of rostrum reddish ochreous; legs fuscous yellow.

Wings rather narrow, pale fuscous yellow; apex acutely elliptical; veins fuscous; cross veins, origin of  $r_1$  and termination bordered with fuscous; pterostigma opaque, fuscous ochreous, connected with the radial branch by a single very short cross vein.

Length of body: ♀ 12–14 mm.

Expanse: 37 mm.

Type: Two female specimens in my collection, captured by the author on Takaoyama, on June 6, 1912.

\* Takao is the name of the mountain near Hachiōji, on which the specimens were captured.

† Black in the living as well as in the dried specimen.

39. *Bittacus marginatus*. n. sp.*Tsumaguro-kagambo-modoki*.

(Pl. XXXVII., fig. 3., ♂; wing—Pl. XXXIII., fig. 10; appendage—Pl. XXXI., figs. 10 a, 10 b.)

Body testaceo-ochreous; apex of head in one specimen and ocellar triangle in the other specimen shining black; ocelli pinkish; eyes blackish or testaceous; antennae ochreous; rostrum in one species testaceous; in one specimen prothorax except the posterior margin and in both specimens mesothorax tinged with piceous; legs fuscous yellow.

Wings pale fuscous yellow, iridescent; origin of  $r_1$  in one specimen spotted with fuscous; the outermost cross veins bordered with fuscous; pterostigma opaque and deeply fuscous; apex of wing clouded with fuscous; veins fuscous; pterostigma joined with the radial branch by a single cross vein (in one specimen even this single cross vein is very obscure).

Abdomen ochreous in one specimen and testaceous in the other; the dorsal appendage of male very conspicuous; it is dorsally erected along the uncus, embracing the latter with its lateral lobes.

Length of body: ♂. 11 mm.; 13 mm.

Expanse: 33 mm.; 35 mm.

Type: Two male specimens in my collection, one captured by Mr. ISSHIKI on Mt. Kōya, Kii, Aug. 18, 1912; one on Mt. Yatsugatake, Kai, Aug. 28, 1912, sent to me by Mr. NAKAHARA.

**Species insufficiently known to me.**40. *Panorpa hageni* Navas.

*Panorpa* — sp. nov., Hagen, "Stett. ent. Zeit., 1867, p. 90"; McLach., Trans. Ent. Soc. Lond., 1875, p. 187.

*Panorpa hageni* Navas, Rev. Russ. Ent., 1909, No. 3, p. 4.

The species was indicated by HAGEN only by the words—"Mit ganz schwarzen weiss gefleckten Flügeln." NAVAS proposed the specific name *hageni* for it without giving its description. The species is therefore to me



quite unrecognizable though it is said to be very closely allied to *Panorpa ocellaris* of NAVAS.

July, 1913.

### Postscript.

While this work was in the press, the following two papers, bearing upon the present subject, appeared:—

PETERSEN, E.: H. SAUTER's Formosa Ausbeute. Planipennia II., Megaloptera and Mecoptera.—Ent. Mitteil., Bd. ii., No. 9, pp. 263–265.

BANKS, N.: Synopsis and descriptions of exotic Neuroptera.—Trans. Amer. Ent. Soc., vol. xxxix., pp. 201–242.

In the former, PETERSEN describes a new species, *Panorpa deceptor*,\* from Formosa, a species closely allied to *P. formosana*. In the latter, BANKS sets forth the classification of Ponorpidae. He includes the genera *Aulops*, *Leptopanorpa*, *Himanturella* (not referred to in this paper) and *Campodotecnium* of ENDERLEIN under the genus *Panorpa*, saying: “*Aulops* Enderl., for those with the subcosta ending long before the stigma separates species which are evidently otherwise very closely allied, moreover the subcosta often bends near middle to the costa, and sometimes connected thereto. The number of cross-veins between anal and auxillary veins has been used, but often varies in the two wings of one specimen; the length of the abdomen is not of generic value, so that *Leptopanorpa*, *Himanturella* and *Campodotecnium* are synonyms of

\* The description of the species is as follows:—

***Panorpa deceptor*** Petersen, Ent. Mitteil., Bd. ii., No. 9, p. 263 (1913).

“♂. Head and rostrum pale brown; above the insertion of the antennae is found a brownish black spot, in which the ocelli are placed. Antennae blackish; the two basal joints pale brown. The dorsum of the prothorax brownish black with some small pale spots. Meso- and metathorax yellowish brown with a broad blackish brown streak along the side margins. The 1<sup>st</sup> to 5<sup>th</sup> segments of the abdomen in the greater part of specimens mostly blackish brown; the rest of abdominal segments, the legs and the underside of thorax pale brown to yellowish brown with exception of the tarsal joints, which are a little darker. The hind border of the third tergite produced into a broad semicircular prolongation. The genital valves short and wide apart. Two curious, very long, threadlike prolongations are placed in the space between the two branches of the forceps. The 2<sup>nd</sup> abdominal segment very short, much broader than long. Wings hyaline with a very faint, yellowish tinge and with sooty-brown bands and markings.”

“♀ has the five basal abdominal segments, generally, more dark coloured than in the male.”

“Length of body 14–15 mm; fore wing 14–15 mm; hind wing 13–14 mm.”

“10 ♂♂ and 19 ♀♀, Taihorin, 7. XI. 1911; 1 ♂ and 6 ♀♀, Taihorinsho, 7. IX. and 7. XI.; 1 ♂, Kosempo, 7. VII. 1911; 2 ♂♂, 1 ♀. Sokutsu, V. 1912; 3 ♀♀, Anping.”



*Panorpa*." Except relating to *Leptopanorpa*, this statement agrees well with the facts I have explained in this paper, so I am pleased that my proposal has been partly confirmed by him. About *Leptopanorpa*, however, I cannot agree with him, though I have not yet seen any specimen of the genus. If my understanding of M'LACHLAN's original description of the genus is correct, it can never be synonymous with *Panorpa*. Amongst other things, M'LACHLAN says of the abdomen of *Leptopanorpa*, "the basal (unmodified) segments long (not transverse as in *Panorpa*)." So long as *Panorpa* has the first abdominal segment conspicuously modified, the above stated characters would be sufficient to separate the two genera—moreover possibly to erect *Leptopanorpa* to a special subfamily or even to a special family.

Besides, he has amalgamated *Diplostigma* into synonyms of *Bittacus*. This agrees well with my opinion, as stated in this paper.

Nov. 5, 1913.

On account of an accidental damage to a part of the lithographic block, the lithographer re-drew the figures on the stone omitting, however, my rectifications. Owing to this the venations of the wings in figs. 10 a and 11 may not be quite accurate.

Nov. 29, 1913.

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## EXPLANATION OF PLATES.

## List of abbreviations.

<i>a.</i>	Anus.		
<i>a. b.</i>	Basal joints of the female appendage.	<i>d. ap.</i>	of bursa copulatrix.
<i>a. br.</i>	Branched portion of the female appendage.	<i>d. p.</i>	Dorsal appendage.
<i>a. br'.</i>	Female appendage.	<i>e.</i>	Dorsal plate.
<i>ad. s.</i>	Additional segment; pedes genitales.	<i>em.</i>	Eye.
<i>af.</i>	Antennal foramen.	<i>ep.</i>	Epimeron.
<i>a. g.</i>	Accessory gland.	<i>epc.</i>	Epithelium.
<i>an.</i>	Anal.	<i>es.</i>	Epicranium.
<i>an<sub>1</sub>, an<sub>2</sub>, an<sub>3</sub>.</i>	Division of anal.	<i>f.</i>	Episternum.
<i>bas. p.</i>	Basal piece (of the labial palpi).	<i>g.</i>	Femur.
<i>bur.</i>	Bursa copulatrix.	<i>g.</i>	Gena.
<i>c.</i>	Postclypeus; clypeus.	<i>ga.</i>	Galea.
<i>c. (in the wing).</i>	Costa.	<i>ga<sub>1</sub>, ga<sub>2</sub>.</i>	Division of galea.
<i>c'.</i>	Anteclypeus.	<i>g. p.</i>	Genital portion.
<i>ca.</i>	Cardo.	<i>g. r.</i>	Genal region.
<i>c. b.</i>	Cylindrical body.	<i>har.</i>	Harpe.
<i>cer.</i>	Cercus.	<i>i. s.</i>	Internal skeleton.
<i>c. f.</i>	Chitinous filament.	<i>int.</i>	Intestine.
<i>c. f. w.</i>	Chitinous frame-work.	<i>j.</i>	Small joint.
<i>c. g.</i>	Colleterial glands.	<i>l.</i>	Labrum.
<i>c. pl.</i>	Chitinous plate.	<i>la.</i>	Lacinia.
<i>c. pie.</i>	Chitinous pieces.	<i>la<sub>1</sub>, la<sub>2</sub>, la<sub>3</sub>.</i>	Division of lacinia.
<i>c. py.</i>	Chitinous pyramid.	<i>l. a. g.</i>	Last abdominal ganglion.
<i>c. r.</i>	Chitinous rod.	<i>l. ap.</i>	Lateral appendage.
<i>cu.</i>	Cubitus.	<i>lbi.</i>	Labium.
<i>cu<sub>1</sub>, cu<sub>2</sub>.</i>	Branches of cubitus.	<i>li.</i>	Ligula.
<i>c. v. b.</i>	Vesicular bodies.	<i>l. m.</i>	Longitudinal muscle.
<i>cox.</i>	Coxa.	<i>l. p.</i>	Labial palpi.
<i>d.</i>	Duct of seminal vesicle, or	<i>m.</i>	Mandible.
		<i>m. (in the wing).</i>	Media.
		<i>m<sub>1</sub>, m<sub>2</sub>, m<sub>3</sub>, m<sub>4</sub>.</i>	Branches of media.
		<i>m. ap.</i>	Middle appendage.
		<i>me.</i>	Meron.
		<i>men.</i>	Mentum.



<i>meso.</i>	Mesothorax.		region.
<i>meta.</i>	Metathorax.	<i>s. g.</i>	Salivary glands.
<i>mi.</i>	Mid-intestine.	<i>sc.</i>	Subcosta.
<i>m. pl.</i>	Bundle of supporting muscles.	<i>s. c.</i>	Small chitinous plate.
<i>m. p. tb.</i>	Malpighian tubes.	<i>sc<sub>1</sub>.</i>	Præscutum.
<i>mx.</i>	Maxilla.	<i>sc<sub>2</sub>.</i>	Scutum.
<i>mx. p.</i>	Maxillary palp.	<i>sc<sub>3</sub>.</i>	Scutellum.
<i>nv.</i>	Nerve.	<i>sc<sub>4</sub>.</i>	Postscutellum.
<i>oc.</i>	Ocelli.	<i>se.</i>	Seta.
<i>occ.</i>	Occiput.	<i>sp.</i>	Spiracle.
<i>oc. f.</i>	Occipital foramen.	<i>s. p.</i>	Subgenital plate; sternal portion.
<i>oe.</i>	Oesophagus.	<i>spu.</i>	Spur.
<i>ov.</i>	Ovary.	<i>st.</i>	Stipes
<i>ovid.</i>	Oviduct.	<i>sub.</i>	Submentum.
<i>ovid. c.</i>	Common oviduct.	<i>t.</i>	Testis.
<i>p. (Pl. II.).</i>	Patagia.	<i>tb.</i>	Tibia.
<i>p. (Pl. V.).</i>	Opening of male genital duct.	<i>tr.</i>	Trochanter.
<i>pf.</i>	Palpifer.	<i>tr. p.</i>	Triangular plate.
<i>pg.</i>	Postgena.	<i>ts.</i>	Tarsus.
<i>p. g.</i>	Pedes genitales.	<i>ts<sub>1</sub>, ts<sub>2</sub>, ts<sub>3</sub>, ts<sub>4</sub>, ts<sub>5</sub>.</i>	Tarsal joints.
<i>pgf.</i>	Palpiger.	<i>un.</i>	Uncus.
<i>p. p.</i>	Posterior chitinous plate.	<i>v. (Pl. I.).</i>	Vertex.
<i>pro.</i>	Prothorax.	<i>v. (Pl. IV., V.).</i>	Vesicle.
<i>ptr.</i>	Pterostigma.	<i>v. ap.</i>	Ventral appendage.
<i>pvl.</i>	Pulvillus.	<i>v. d.</i>	Vas deferens.
<i>pv.</i>	Proventriculus.	<i>v. e.</i>	Vasa efferentia.
<i>r.</i>	Radius.	<i>v. p.</i>	Ventral plate.
<i>r<sub>1</sub>, r<sub>2</sub>, r<sub>3</sub>, r<sub>4</sub>, r<sub>5</sub>.</i>	Branches of radius.	<i>v. r.</i>	The region where the vesicle is found.
<i>rec.</i>	Rectum.	<i>v. s.</i>	Vesicla seminalis.
<i>r. m.</i>	Ring muscle.	<i>1...x.</i>	Number of segments.
<i>s.</i>	Suture found on the genal		

## PLATE XXVIII.

- Fig. 1. Head of *Panorpa klugi*, anterior view.  $\times 8$ .  
 Fig. 2. Do., posterior view.  $\times 8$ .  
 Fig. 3. Head of *Panorpodes paradoxa*, anterior view.  $\times 8$ .  
 Fig. 4. Do., posterior view.  $\times 8$ .

- Fig. 5. Head of *Bittacus nipponicus*, anterior view.  $\times 8$ .  
 Fig. 6. Do., posterior view.  $\times 8$ .  
 Fig. 7. Left mandible of *Panorpodes paradoxa*.  $\times 35$ .  
 Fig. 8. Do. of *Panorpa klugi*.  $\times 35$ .  
 Fig. 9. Do. of *Bittacus nipponicus*.  $\times 35$ .  
 Fig. 10. Labrum of *Panorpa klugi*.  $\times 35$ .  
 Fig. 11. Do. of *Panorpodes paradoxa*.  $\times 35$ .  
 Fig. 12. Do. of *Bittacus nipponicus*.  $\times 35$ .  
 Fig. 13. Labium of *Panorpa klugi*.  $\times 35$ .  
 Fig. 14. Do. of *Panorpodes decorata*.  $\times 35$ .  
 Fig. 15. Do. of *Bittacus nipponicus*.  $\times 35$ .  
 Fig. 16. Left maxilla of *Panorpa klugi*.  $\times 35$ .  
 Fig. 17. Do. of *Panorpodes decorata*.  $\times 35$ .  
 Fig. 18. Do. of *Bittacus nipponicus*.  $\times 35$ .  
 Fig. 19a. Basal segments of antenna of *Panorpa klugi*.  $\times 23$ .  
 Fig. 19b. Terminal segments of do.  $\times 23$ .  
 Fig. 20a. Basal segments of antenna of *Panorpodes decorata*.  $\times 23$ .  
 Fig. 20b. Terminal segments of do.  $\times 23$ .  
 Fig. 21a. Basal segments of antenna of *Bittacus nipponicus*.  $\times 23$ .  
 Fig. 21b. Terminal segments of do.  $\times 300$ .

## PLATE XXIX.

- Fig. 1. Thorax of *Panorpa klugi*, dorsal view.  $\times 7$ .  
 Fig. 2. Do. of *Panorpodes decorata*, dorsal view.  $\times 7$ .  
 Fig. 3. Do. of *Bittacus nipponicus*, dorsal view.  $\times 7$ .  
 Fig. 4. Do. of *Panorpa klugi*, lateral view.  $\times 4$ .  
 Fig. 5. Do. of *Panorpodes decorata*, lateral view.  $\times 4$ .  
 Fig. 6. Do. of *Bittacus nipponicus*, lateral view.  $\times 4$ .  
 Fig. 7. Hypopharynx of *Panorpa klugi*.  $\times 130$ .  
 Fig. 8. Do. of *Panorpodes decorata*.  $\times 130$ .  
 Fig. 9. Do. of *Bittacus nipponicus*.  $\times 130$ .  
 Fig. 10. Tibial spurs of left fore leg of *Bittacus nipponicus*.  $\times 23$ .  
 Fig. 11. Tarsus of left fore leg of *Panorpa klugi*.  $\times 23$ .  
 Fig. 12a. Tarsal joints of left fore leg of *Bittacus nipponicus*, extended.  $\times 23$ .  
 Fig. 12b. Do., apposed.  $\times 23$ .  
 Fig. 13a. Teeth on the last tarsal joints of *Bittacus nipponicus*.  $\times 600$ .  
 Fig. 13b. Teeth on the fourth tarsal joint of do.  $\times 600$ .  
 Fig. 14a. Sixth and seventh abdominal segments of *Panorpa cornigera*, lateral view.  $\times 8$ .  
 Fig. 14b. Do., dorsal view.  $\times 8$ .  
 Fig. 15. Abdominal segments of male of *Panorpa takenouchii*, lateral view.  $\times 4$ .

- Fig. 16. Abdomen of male of *Panorpa klugi*, lateral view.  $\times 4$ .  
 Fig. 17a. Abdomen of female of *Panorpa klugi*, lateral view.  $\times 4$ .  
 Fig. 17b. Seventh and eighth abdominal segments of do.  $\times 8$ .  
 Fig. 18. Abdomen of male of *Panorpodes decorata*, lateral view.  $\times 4$ .  
 Fig. 19. Abdomen of female of *Panorpodes decorata*, lateral view.  $\times 4$ .  
 Fig. 20. Abdomen of male of *Bittacus nipponicus*, lateral view.  $\times 4$ .  
 Fig. 21. Abdomen of female of *Bittacus nipponicus*, lateral view.  $\times 4$ .

## PLATE XXX.

- Fig. 1. Cheliferous segment of *Panorpa klugi*, ventral view.  $\times 23$ .  
 Fig. 2. Do. of *P. cornigera*, ventral view.  $\times 23$ .  
 Fig. 3. Do. of *P. takenouchii*, ventral view.  $\times 23$ .  
 Fig. 4. Do. of *P. pryeri*, ventral view.  $\times 23$ .  
 Fig. 5a. Dorsal appendage of male of *P. klugi*, dorsal view; the cerci of anal tube can be seen projecting laterally.  $\times 23$ .  
 Fig. 5b. Anal tube of do., ventral view.  $\times 23$ .  
 Fig. 6. Terminal segments of female abdomen of *P. klugi*, with appendages, lateral view.  $\times 23$ .  
 Fig. 7. Appendages of female of *P. klugi*, dorsal view.  $\times 23$ .  
 Fig. 8. Sternal plate of female of *P. klugi*, ventral view.  $\times 23$ .  
 Fig. 9. Internal skeleton of the ninth segment in the female of *P. klugi*.  $\times 42$ .  
 Fig. 10. Dorsal and ventral appendages of male of *P. klugi*, lateral view.  $\times 23$ .  
 Fig. 11a. Conical projection of the fourth abdominal segment of male of *P. klugi*, dorsal view.  $\times 42$ .  
 Fig. 11b. Dorsal lobe of the third abdominal segment of do., ventral view.  $\times 42$ .  
 Fig. 11c. Do., dorsal view.  $\times 42$ .  
 Fig. 12. Ventral appendage of male of *P. pryeri*, ventral view.  $\times 23$ .  
 Fig. 13a. Do. of *P. cornigera*.  $\times 23$ .  
 Fig. 13b. Dorsal appendage of do., dorsal view.  $\times 23$ .  
 Fig. 14-20. Ventral appendages of males of various species. Fig. 14. *japonica*.  $\times 23$ . Figs. 15-20.  $\times$  about 8. Fig. 15. *levisi*; fig. 16. *rectifasciata*; fig. 17. *pulchra*; fig. 18. *klugi*; fig. 19. *ochracea*; fig. 20. *klugi*, varietal form.  
 Fig. 21. Dorsal appendage of male of *P. wormaldi*.  $\times 23$ .

## PLATE XXXI.

- Fig. 1. Cheliferous segment of *Panorpodes decorata*, dorsal view.  $\times 23$ .  
 Fig. 2. Terminal segments of female abdomen of *Bittacus nipponicus*, ventral view.  $\times 23$ .  
 Fig. 3a. Abdominal end of male of do., posterior view.  $\times 23$ .  
 Fig. 3b. The basal part of the dorsal appendage of do., showing the anus, posterior view.  $\times 35$ .

- Fig. 3c. The basal part of the posterior chitinous plate of male, anterior view.  $\times 35$ .
- Fig. 4. Terminal segments of male abdomen of do., showing the main parts of genitalia, lateral view.  $\times 23$ .
- Fig. 5a. Dorsal appendage of male of *Panorpodes decorata*, with the anal tube, dorsal view.  $\times 23$ .
- Fig. 5b. Anal tube of do., ventral view.  $\times 23$ .
- Fig. 6. Left appendage of female of *Bittacus nipponicus*.  $\times 160$ .
- Fig. 7. One of the hairs on do., with cup-like envelope.  $\times 600$ .
- Fig. 8a. Ventral appendage of *Panorpodes decorata*, ventral view.  $\times 23$ .
- Fig. 8b. Dorsal appendage of do., dorsal view.  $\times 23$ .
- Fig. 9a. Terminal segments of female abdomen of *Panorpodes decorata*, dorsal view.  $\times 23$ .
- Fig. 9b. Internal skeleton of do.  $\times 160$ .
- Fig. 10a. Last abdominal segments of male of *Bittacus marginatus* n. sp., posterior view.  $\times$  about 8.
- Fig. 10b. Do., lateral view.  $\times$  about 8.
- Figs. 11-18. Male ventral appendages of various species.  $\times$  about 8. Fig. 11. *communis*; fig. 12. *arakavae*; fig. 13. *leucoptera*; fig. 14. *wormaldi*; fig. 15. *gokaensis*; fig. 16. *bicornuta*; fig. 17. *obscura*; fig. 18. *ochraceopennis*.

## PLATE XXXII.

- Fig. 1. Female reproductive system of *Panorpa klugi*.
- Fig. 2. Male reproductive system of do.
- Fig. 3. Digestive system of do.
- Fig. 4. Histology of proventriculus of *Panorpa klugi* (transverse section).  $\times 400$ .
- Fig. 5. Diagrammatic transverse section of do.  $\times 35$ .
- Fig. 6. Diagrammatic longitudinal section of do.  $\times 35$ .
- Fig. 7. Testis and accessory gland of *Panorpodes decorata*.  $\times 23$ .
- Fig. 8. Egg of *Bittacus nipponicus*.  $\times 23$ .
- Fig. 9. Anterior portion of the alimentary canal, where bundles of supporting muscles are found.  $\times 80$ .

## PLATE XXXIII.

- Fig. 1. Right fore and hind wings of *Bittacus nipponicus*.  $\times 5$ .
- Fig. 2. Do. of *Panorpa klugi*.  $\times 5$ .
- Fig. 3. Do. of *Panarpodes decorata*.  $\times 5$ .
- Fig. 4. Do. of *Panorpa cornigera*.  $\times 5$ .
- Fig. 5. Basal portion of right hind wing of *Panorpa klugi*.  $\times 23$ .



Fig. 6.\* Right fore and hind wings of *Billacus quaternipunctatus*.  $\times 2$ .

Fig. 7.\* Do. of *B. nipponicus*.  $\times 2$ .

Fig. 8.\* Do. of *B. takaoensis* n. sp.  $\times 2$ .

Fig. 9.\* Do. of *B. laevipes*.  $\times 2$ .

Fig. 10.\* Do. of *B. marginalis*.  $\times 2$ .

## PLATE XXXIV.

Figs. 1-8 illustrate gradual modifications of the subcosta: (R) indicate the right wing; (L) the left wing; dotted lines indicate obsolete veins.  $\times 25$ .

Figs. 9a, 9b. Terminations of the subcosta on the costa (*Panorpa lewisi*).  $\times 25$ .

Fig. 10a,† *Panorpa galloisi*, ♂.  $\times 2$ .

Fig. 10b. Apex of abdomen of do.  $\times$  about 15.

Fig. 10c. Ventral appendage of do.  $\times$  about 8.

Fig. 11,† *Panorpodes decorata confusa* n. subsp. ♀.  $\times 2$ .

Fig. 12a. Apex of abdomen of *Panorpa trizonata* ♂.  $\times$  about 5.

Fig. 12b. Ventral appendage of do.  $\times$  about 8.

## PLATE XXXV.

All figures are slightly enlarged.

Fig. 1. *Panorpa japonica* Thunb., ♂.

Fig. 2. Do., ♂.

Fig. 3. Do., ♂.

Fig. 4. *P. pulchra* Miyake, ♀.

Fig. 5. *P. japonica* Thunb., ♂.

Fig. 6. Do., ♀.

Fig. 7. *P. rectifasciata* Miyake, ♂.

Fig. 8. Do., ♀.

Fig. 9. *P. pulchra* Miyake, ♂.

Fig. 10. *P. klugi* McLach., ♂.

Fig. 11. *P. klugi maculata* n. subsp., ♀.

Fig. 12. *P. klugi quadrimaculata* n. subsp., ♀.

Fig. 13. *P. klugi nipponensis* Navas, ♀.

Fig. 14. Do., varietal form, ♂.

Fig. 15. *P. ochraceopennis* Miyake, ♂.

Fig. 16. *P. lewisi* McLach., ♂.

Fig. 17. *P. trizonata* Miyake, ♂.

Fig. 18. Do., ♂.

\* Figs. 6-10 are drawn only to show the general appearance of wings of our *Billacus*. The minute points of venation, especially those of the basal region, are omitted.

† The venations of the wings in figs. 10a and 11 may not be quite accurate (see p. 391).

## PLATE XXXVI.

All figures are slightly enlarged.

- Fig. 1. *Panorpa bicornuta* M'Lach., ♂.
- Fig. 2. Do., ♀.
- Fig. 3. *P. gokaensis* Miyake, ♀.
- Fig. 4. *P. nikkoensis* Miyake, ♀.
- Fig. 5. *P. cornigera* M'Lach., ♂.
- Fig. 6. Do., varietal form, ♀.
- Fig. 7. *P. takenouchii* Miyake, ♀.
- Fig. 8. *P. arakavae* n. sp., ♂.
- Fig. 9. *P. hakusanensis* n. sp., ♀.
- Fig. 10. *P. takenouchii* Miyake, ♂.
- Fig. 11. *P. ochracea* Miyake., ♂.
- Fig. 12. *P. pryeri major* Miyake, ♀.
- Fig. 13. *P. pryeri* M'Lach., ♂.
- Fig. 14. Do., ♂.
- Fig. 15. Do., ♂.
- Fig. 16. *P. leucoptera* Uhl., ♀.
- Fig. 17. Do., ♂.
- Fig. 18. *P. wormaldi* M'Lach., ♂.
- Fig. 19. *P. striata* Miyake, ♂.
- Fig. 20. *P. multifasciaria* Miyake, ♀.
- Fig. 21. *P. communis* L., ♂.
- Fig. 22. *P. obscura* Miyake, ♂.

## PLATE XXXVII.

Figs. 1-10 are slightly enlarged and figs. 11-34 are slightly reduced.

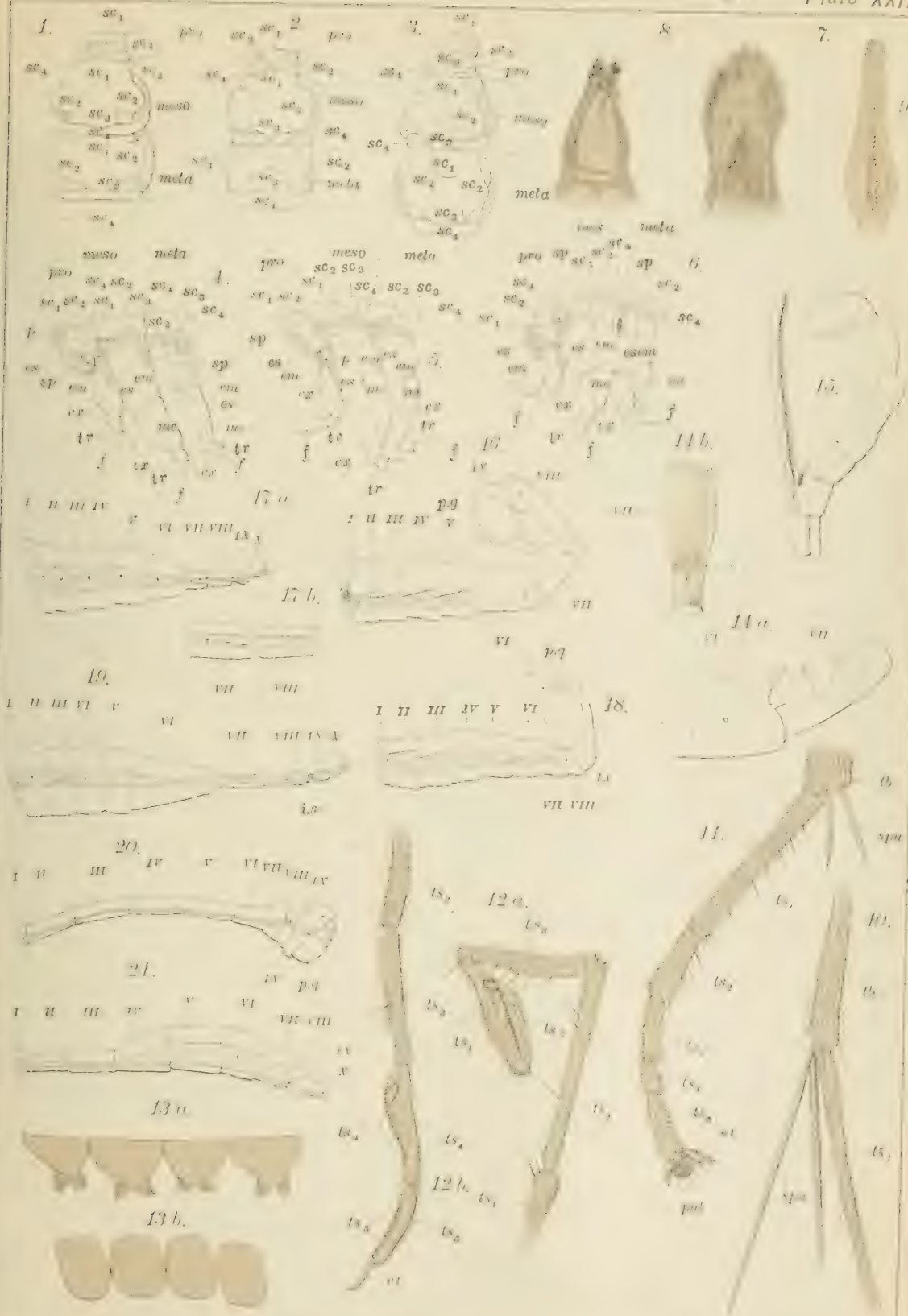
- Fig. 1. *Panorpodes paradoxa* M'Lach., ♂.
- Fig. 2. *P. paradoxa stigmatica* n. subsp., ♀.
- Fig. 3. *P. naevia* Navas, ♀.
- Fig. 4. *P. decorata singularis* Miyake, ♀.
- Fig. 5. *P. decorata limbata* Navas, ♀.
- Fig. 6. *P. decorata confusa* n. subsp., ♀.
- Fig. 7. *P. decorata* M'Lach., ♀.
- Fig. 8. *Bittacus marginatus* n. sp., ♂.
- Fig. 9. *B. laevipes* Navas, ♀.
- Fig. 10. *B. quaternipunctatus* End., ♀.

Figs. 11-34 represent variations of wing-markings of *Panorpa klugi*: figs. 11-28 subsp. *nipponeensis*; figs. 29-32 subsp. *maculata* n. subsp.; figs. 33-34 subsp. *quadrimaculata* n. subsp.

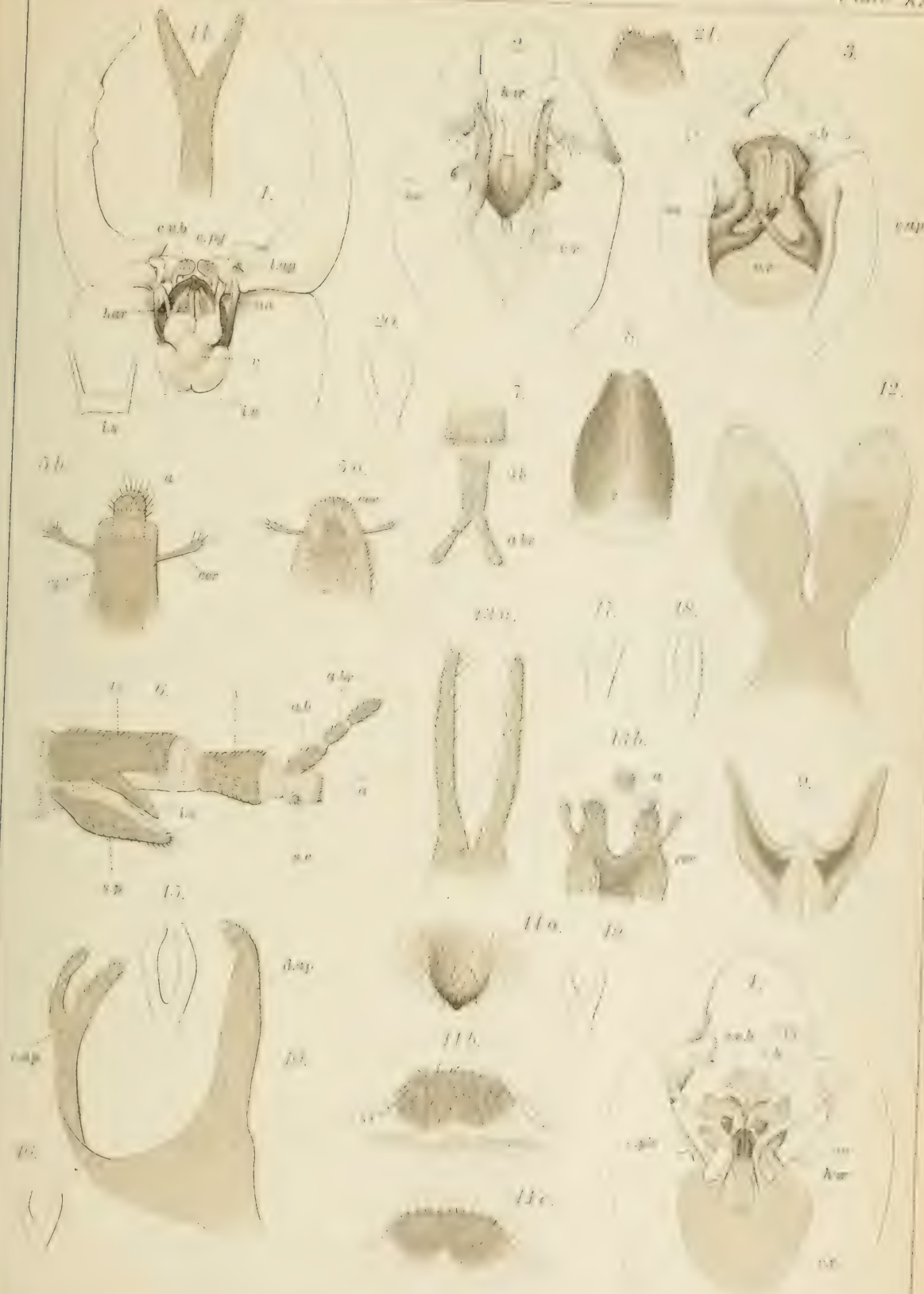










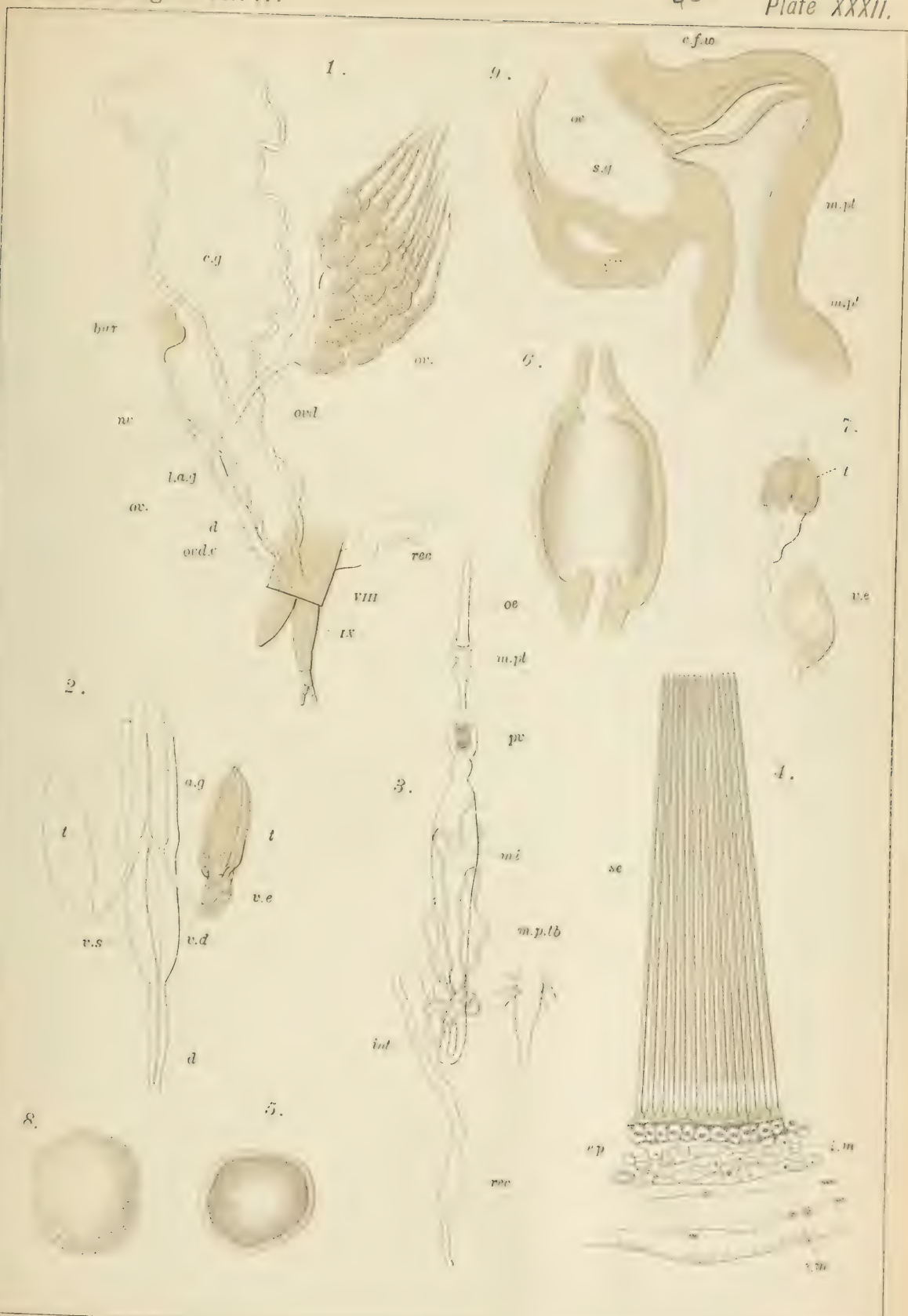










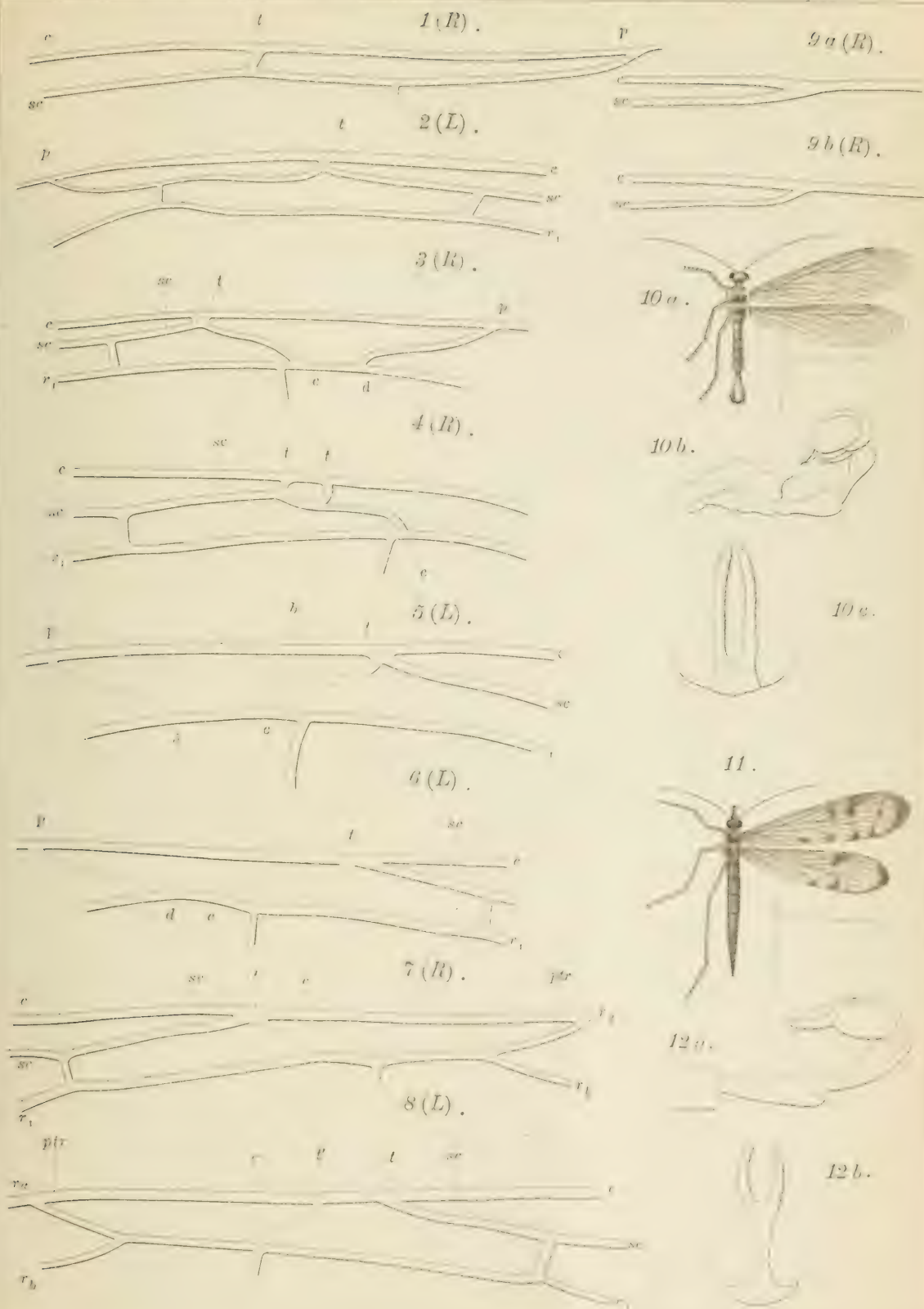








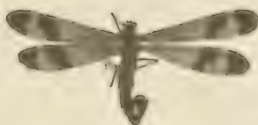
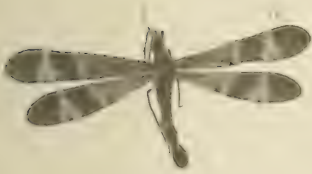
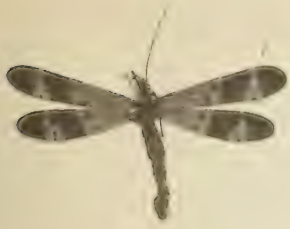








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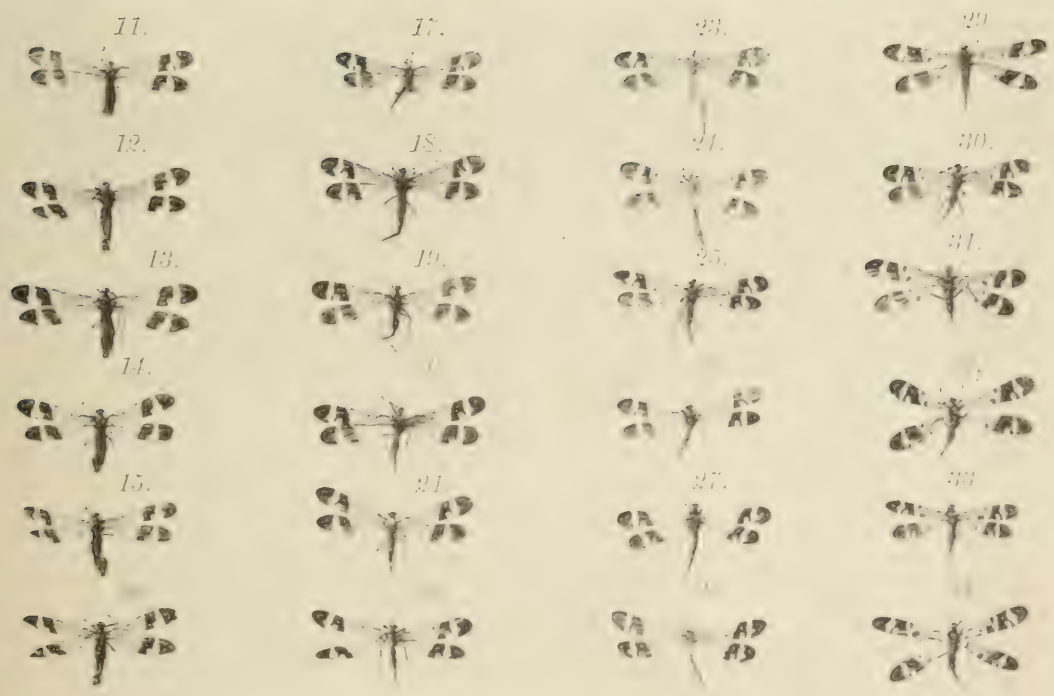














Über eine neue Art von *Enoploteuthis*,  
*Enoploteuthis chunii*<sup>1</sup> spec. nov, aus  
Uwodu, Japanisches Meer.

VON

C. Ishikawa.

Mit Tafeln XXXVIII und XXXIX.

Mantelgestalt länglich, vorderer Rand etwas verbreitert, mit dorsalen konvexen Profilkurven, allmählich sich verjüngend bis zur hinteren Spitze, welche um etwa ein Sechstel der ganzen Mantellänge aus dem hinteren Flossenende überragt. Dieser Teil des Mantelendes ist gallertig und ziemlich steil nach unten gebogen. In der dorsalen Mittellinie zeigt der vordere Mantelrand einen stumpfen vorziehenden Winkel, der bei verschiedenen Individuen etwas verschieden ausgebildet zu sein scheint, wie aus dem Aussehen der konservierten Exemplare zu schliessen ist. An beiden Seiten der Winkel bildet der Mantelrand einen kleinen Bogen bis zu den Ecken der Auskehrung des vorderen Mantelrandes auf der Bauchfläche. An der Medianlinie dieser Auskehrung findet man einen kleinen Winkel, welcher jedoch nicht bei allen Tieren zu sehen ist.

Die Flosse ist gross, subterminal; das hintere Mantelende ragt, wie gesagt, über das hintere Flossenende hinüber. Die vorderen Ränder der Flosse konvex, die Posterolateralränder zuerst konvex, nach hinten jedoch etwas konkav. Die Seitenecken der Flosse bilden einen stumpfen abgerundeten Winkel. Als Ganzes betrachtet hat die Flosse eine mit einem Gingko-Blatt vergleichbare Gestalt.

<sup>1</sup> Dediziert dem bekannten Tiefseeforscher und Teuthologen Herrn Geheimen Rat Professor Dr. Carl Chun.

Der Kopf ist schmaler als die Mantelöffnung, mehr oder weniger kantig, oben platt, unten etwas konkav; der Augenteil nicht aufgetrieben. Die Augenöffnung sehr gross, vorn mit tiefem Sinus, der nahe an dem ventralen Teile des vorderen Randes des Auges liegt.

Die vordere Ringkante des Halses ist ziemlich gut ausgebildet. Sie bildet aber keine hochstehende Falte. Zwischen der ersten und der zweiten Längsfalte ist sie nicht sehr deutlich zu sehen; zwischen der zweiten und der dritten, sowie der dritten und der vierten, bildet sie eine nach hinten konkave Linie, um in der dorsalen Mittellinie in einem scharf ausgeprägten stumpfen Winkel zu endigen. Die erste Längsfalte klein, von dreieckiger Gestalt. Sie verläuft nach hinten dorsal gerichtet, und verstreift allmählich. Die zweite Falte ist höher und auch grösser, vorn höher entwickelt als hinten; sie bildet einen Bogen nach hinten und dorsal, um mit der hinteren Ringkante des Halses zusammenzulaufen. Die dritte Falte ist die höchste; sie erscheint als ein länglich halbmond-förmiger Lappen, verläuft ziemlich gerade nach hinten, und bildet mit der hinteren Ringkante des Halses einen rechten Winkel. Die hintere Ringkante des Halses ist nur zwischen der zweiten und dritten Längsfalte und zwischen der dritten und der Mittellinie des Halses gut ausgeprägt; ventral von der zweiten Längsfalte ist sie nicht deutlich zu bemerken, wenigstens nicht bei den konservierten Exemplaren, die wir vor uns haben.

Der Trichter ist von normaler Gestalt und ragt ein wenig hinter den hinteren Augenrand. Die Trichtergrube ist tief und deutlich, von dreieckigem Umriß. Die Trichterklappe und die Trichterorgane sind wohl entwickelt. Jede der ventralen Trichterorgane ist von länglich-ovaler Gestalt. Der unpaare dorsale Abschnitt nimmt eine breite V-förmige Gestalt an, das hintere Ende über die Trichterdepressoren deckend. Der Trichterknorpel ist länglich, der ventrale Rand etwas breiter als der dorsale, die Längsgrube ein wenig breiter in der posterioren Partie. Der Mantelknorpel ist schmal und gerade, oder ein wenig gebogen wie die Trichterknorpelgrube. Der *Musculus collaris* ist breit und zieht sich zum Nackenknorpel, welcher eine längliche Platte mit abgerundeten Enden darstellt, deren anteriores Ende breiter ist als das posteriore. Die beiden seitlichen Ränder des Nackenknorpels sind dicker als die mittlere Partie, welche eine leichte



Vorwölbung zeigt. Der entsprechende dorsale Mantelknorpel besitzt parallel laufende Ränder und eine mediane Leiste.

Der Buccaltrichter ist gut entwickelt, mit acht Zipfeln, von denen die beiden dorsalen etwas mehr genähert sind als die anderen, und die beiden ventralen vielleicht etwas länger; wenigstens sind die Einkerbungen zwischen den beiden ventralen und den benachbarten Zipfeln tiefer als zwischen den anderen. Die Heftungen zeigen die übrigen Verhältnisse wie bei den *Enoploteuthiden*, d.h. die ersten und zweiten Armpaare haften dorsal, die dritten ventral und die vierten wiederum dorsal.

Die Arme haben eine mässige Länge und betragen ungefähr ein Sechstel der Mantellänge; das gegenseitige Verhältnis wird durch die Formel 4,3,2,1 oder 4,2,3,1 ausgedrückt.

I. Masse von *Enoploteuthis chunii* nach vorliegenden Exemplaren in mm:—

	Mantel- länge.	Mantel- breite.	Flossen- länge.	Flossen- breite.	Rechte Arme. I. II. III. IV.				Rechter Tentakel.	Linke Arme. I. II. III. IV.				Linker Tentakel.
I.	72	20	41	54	46	50	48	53	95	43	48	51	51	100
II.	68	20	40	51	43	52	53	51	100	43	48	45	49	95
III.	75	23	41	53	39	41	40	42	92	36	40	40	44	100
IV.	70	22	41	53	36	43	46	46	96	36	40	39	45	?
V.	90	49	49	66	50	50	51	57	125	48	52	54	58	125

II. Masse von *Enoploteuthis chunii* in % der dorsalen Mantellänge:—

	Mantel- länge.	Mantel- breite.	Flossen- länge.	Flossen- breite.	Rechte Arme. I. II. III. IV.				Rechter Tentakel.	Linke Arme. I. II. III. IV.				Linker Tentakel.
I.	100	27.77	56.90	75.00	63.88	69.44	66.66	73.75	13.19	59.71	66.66	70.83	70.83	138.88
II.	100	29.41	58.71	75.00	63.23	76.47	77.94	75.00	147.00	63.23	70.58	66.23	72.05	139.70
III.	100	30.66	54.66	70.66	52.00	54.66	53.33	56.00	122.66	48.00	53.33	53.33	58.66	133.33
IV.	100	31.42	58.57	75.71	51.42	61.72	65.71	65.71	137.14	51.42	57.14	55.71	61.28	?
V.	100	54.44	54.44	73.33	55.55	55.55	56.66	63.33	138.88	53.33	57.77	60.00	64.44	138.88

Das erste Paar trägt auf dreiviertel seines distalen Teils einen sehr schmalen Schwimmsaum; der Saum des zweiten Paares ist etwas stärker ausgebildet und fängt auch auf dem ersten Viertel des Armes an; der Saum

des dritten Paares ist, wie gewöhnlich, am stärksten entwickelt; er zeigt sich als ein mächtiger Schwimmlappen, dessen Höhe der Armdicke gleichkommt. Der Schwimmsaum des vierten Paares ist beinahe so gut entwickelt wie der des dritten; die des dritten und vierten Paares fangen von der Basis des betreffenden Armes an.

Die Schutzsäume sind überall gut entwickelt und, wie gewöhnlich, auf der ventralen Kante des Armes stärker als auf der dorsalen. Die Dorsalsäume des ersten, zweiten und dritten Paares sind etwa halb so breit wie der Haken an der betreffenden Stelle des Armes, der des vierten Paares etwas schmaler; auch der ventrale Saum des ersten, zweiten und dritten Paares ist höher als der des vierten Paares, welcher ungefähr halb so breit wie der Haken, während der des ersten, zweiten und dritten Paares so breit wie der Haken ist. Die Querstützen der Schutzsäume sind auf dem ersten, zweiten und dritten Paare gut entwickelt und ragen, wie sonst, über der allgemeinen Kontur des Saumes hinüber. Auf dem vierten Paare fehlen die Querstützen.

Die Arme tragen zwei alternierende Reihen von proximalen grossen Haken und distalen Näpfen. Die Haken des ersten Paares beginnen etwas mehr proximal als die der anderen Arme. Der erste Haken sitzt auf dem ersten, zweiten und vierten Arme in der ventralen Reihe; auf dem dritten in der dorsalen. Auf dem ersten Arme nimmt der distale Napfteil ein Viertel der Länge des Armes ein, der Hakenteil drei Viertel desselben; auf dem zweiten, dritten und vierten Arme nimmt der Napfteil ein Fünftel der Armlänge und der Hakenteil drei Viertel derselben ein. Es scheinen aber einige kleine Verschiedenheiten in Bezug auf die Stelle des ersten Hakens vorzukommen; so habe ich bei einem Exemplar beobachtet, dass der erste Haken auf dem ersten Armpaare am linken Arme etwas mehr proximal anliegt als am rechten, wogegen auf dem dritten und vierten Armpaare der erste Haken umgekehrt liegt. Was die Grösse des Hakens anbetrifft, so sind die ersten oder zweiten Paare immer etwas kleiner als die folgenden. Die grössten Haken sind auf dem ersten und zweiten Arme der fünfte oder der sechste; auf dem dritten Arme der vierte oder der fünfte, und auf dem vierten der dritte, vierte oder der fünfte. Die distalen Haken nehmen ganz allmählich an Grösse ab. Die Grösse der Näpfe nimmt allmählich von dem ersten

bis zum letzten ab. Die Näpfe sind oval; der Chitinring ist am äussersten Rande von einer zweireihigen Stäbchenzone umgeben. Innerhalb dieser Zone besteht der Ring aus zwei Teilen, einem äusseren und einem inneren, welche beide an beiden Enden breiter sind als an den Seiten. Der äussere Teil des Ringes besteht ganz aus polygonalen Plättchen, die in der Mitte in Zähne ausgezogen sind. Diese Plättchen sind auf dem proximalen Teile grösser als auf dem distalen, und in zwei alternierenden Reihen angeordnet, auf dem distalen aber in vier oder fünf Reihen. Der innere Teil des Chitinringes liegt tiefer in den Näpfen als der äussere, und besteht auch aus polygonalen Plättchen wie der äussere. Diese finden sich aber nur auf dem distalen Teile, während der proximale sich als eine zusammenhängende Platte darstellt, die schräg nach der Mündung des Napfes steht. Die Plättchen auf diesem Teile sind bedeutend grösser als die des äusseren Teiles des Ringes und tragen zwei Reihen von ungefähr elf sehr grossen Zähnen, die übereinander stehen; der mittlere gewöhnlich etwas länger als die nebenstehenden, welche allmählich nach den Seiten zu sich verkleinern.

Die Tentakellänge übertrifft die des Mantels; das Verhältnis schwankt beträchtlich, wie man auf der angegebenen Tabelle sieht. Der Tentakelstiel ist plattgedrückt mit abgerundeten Kanten, seine Seitenflächen sind fast doppelt so breit wie seine Oralfläche. Ein niedriger Schwimmsaum ist an dem distalen Ende des Tentakels zu sehen. Er nimmt ungefähr ein Zwanzigstel der Tentakellänge ein und liegt etwas vor dem Karpalpolster gegenüber. Ein zweiter länglicher Saum findet sich an der Spitze des Tentakels; dieser beginnt ziemlich plötzlich etwas distal zu dem ersteren, ungefähr am distalen Drittel des Handteiles des Tentakels, und erhebt sich zu einem mächtig entwickelten Schwimmlappen. Von Anfang an ist er so hoch wie die Seitenfläche des Armes, wird aber gleich breiter und endet plötzlich mit abgerundeten Kanten an der extremen Spitze des Tentakels. Dieser Saum liegt nicht in ein und derselben Linie mit dem ersteren, sondern etwas dorsal zu demselben.

Ventral zu dem distalen Teile der Keule, zwischen dem Ende des Karpalpolsters und dem ersten oder zweiten grossen Haken, findet man



einen länglich halbmondförmigen dritten Saum,<sup>2</sup> der eigentlich den Anfangsteil des ventralen Schutzsaumes darstellt. Er liegt etwas schräg dorsoventral auf der Seitenfläche an und zieht sich als eine sehr niedrige saumartige Erhebung an der Ventralseite der grösseren Hakenreihe resp. der ventralen Reihe der Näpfe entlang. An diesem niedrigen Teil des Schutzsaumes bemerkt man eine Anzahl (meistens drei grössere und zwei oder drei kleinere) Querstützen, die allgemeine Kontur des Saumes überragend. Auch an der dorsalen Basis der Haken, resp. Näpfe, ist ein niedriger Schutzsaum vorhanden, an dem man jedoch keine Querstützen bemerkt.

Der Karpalteil der Keule besteht aus einer Gruppe von vier bis sechs Näpfen und Haftknöpfen. Diese Näpfe sind von plattgedrückter halbkugeliger Gestalt, mit einem Chitinringe, der von zwei kragen-ähnlichen Säumen umgeben ist, deren innerer aus einer Reihe von Stäbchen besteht. Der grössere Teil des Ringes, der innerhalb dieser Säume sich befindet, besteht aus zwei Teilen, einem äusseren oder oberen, der in polygonale Plättchen eingeteilt ist, und einem inneren oder unteren, der aus einer ungeteilten Platte besteht. Die Polygonalplättchen sind in vier bis sechs Reihen angeordnet und entbehren der Zähne. Die Zahl der Näpfe in den vier Exemplaren, die wir untersucht haben, ist wie folgt:—

Links :

No. I, 5 Näpfe und 4 Haftknöpfe (fängt mit einem medio-dorsalen Napf an).

No. II, 4 Näpfe und 6 Haftknöpfe (fängt mit einem medio-ventralen Haftknopf an).

No. III, 5 Näpfe und 4 Haftknöpfe (fängt mit einem medianen Napf an).

No. IV, 4 Näpfe und 4 Haftknöpfe (fängt mit einem medio-dorsalen Napf an).

<sup>2</sup> Eine kleine Verschiedenheit ist in der Lage dieses dritten Saumes zu beobachten.



Rechts:

No. I, 4 Näpfe und 5 Haftknöpfe (fängt mit einem medio-ventralen Napf an)

No. II, 6 Näpfe und 3 Haftknöpfe (fängt mit einem medio-ventralen Napf an)

No. III, 4 Näpfe und 5 Haftknöpfe (fängt mit einem medianen Haftknopf an).

No. IV, 4 Näpfe und 4 Haftknöpfe (ein medio-ventraler Napf und ein medio-dorsaler Haftknopf liegen in einer Ebene).

Die Näpfe sind nicht von gleicher Grösse, sondern es zeigt sich, dass einer von den medio-ventralen immer etwas an Grösse die übrigen übertrifft. Auf dem Handteil ist die ventrale Marginalreihe unterdrückt; es finden sich eine medio-ventrale und eine medio-dorsale Reihe von Haken und Näpfen, die alternierend neben einander stehen. Die Zahl der medio-ventralen Haken beläuft sich auf vier bis sechs, und diese sind viel grösser als die der medio-dorsalen Reihe. In einigen Fällen aber zeigt sich der erste proximale Haken dieser Reihe kleiner als die folgenden. In der medio-dorsalen Reihe sind drei bis vier Haken zu finden; der erste findet sich immer proximal zu den medio-ventralen Haken. Proximal zu der medio-ventralen Reihe von Haken und in derselben Reihe lassen sich zwei gestielte Näpfe finden. Ein oder zwei solche finden sich auch an der medio-dorsalen Reihe. In der dorsalen Marginalreihe gibt es auch einige solche Näpfe. Auf dem Distalteile der Keule finden sich zunächst einige Gruppen von gestielten Näpfen, welche distalwärts kleiner werden und in regelmässigen Vierergruppen stehen.

Die Chitinringe der Saugnäpfe des Handteiles zeigen zwei Reihen von Stäbchenzonen und in Zähne ausgezogene Plasterplättchen wie die der Arme, nur mit dem Unterschied, dass der Ring aus einem Teile besteht, der dem des äusseren des Armes entspricht. Auch ist der Ring ringsum von ungefähr derselben Breite. Wie bei den Armnäpfen sind die Plättchen grösser auf dem proximalen als auf dem distalen Teile, und bestehen aus drei bis vier Reihen mit grösseren Zähnen, während auf dem distalen Teile die Plättchen samt den Zähnen kleiner sind und aus vier bis fünf Reihen

bestehen. Die distalen Zähne, die auf dem innersten Rande des Ringes stehen, sind etwas grösser als die proximalen.

Der äussere Rand des Chitirings ist nicht ganz rund, sondern kurz eiförmig und zwar länger am distalen Ende. Aber die innere Öffnung des Ringes zeigt sich von beinahe rundlicher Gestalt, so dass der Rand des Ringes nicht überall gleichbreit ist; er ist vielmehr am distalen Ende breiter als am proximalen. Die Stäbchen an dem proximalen Ende des Ringes stehen in radialer Richtung, gehen aber immer mehr in eine subtangentialen über, je mehr sie sich dem distalen Ende des Ringes nähern, so dass in der Mittellinie ihre freien Enden von einander abstehen. Auch die einzelnen Stäbchen sind am proximalen Ende des Ringes grösser als am distalen.

Der Gladius ist dunkler gefärbt und stark chitinisirt, etwa im Winkel von  $90^\circ$  dachförmig eingeklappt. Die freie Rhachis erreicht zwei Neuntel der Gesamtlänge. Die Fahne lanzettförmig, ihre Breite ein Siebentel der Länge. Sie verbreitert sich zunächst ziemlich schnell mit wenig gebogener Anterolateralkante, biegt dann mit abgerundeter Ecke, die etwa bei zwei Fünftel der Länge liegt, in die gerade Posterolateralkante um. Die halbrinnenförmige Mittelrippe der Rhachis erhebt sich in der Mittellinie zu einem soliden Kiel; die Seitenrippen der Rhachis sind kräftig entwickelt und zeigen feine Längsstreifungen. Von den Seitenecken der Fahne aus geht die submarginale Verdickung, die etwas schräg zu der hinteren Spitze des Gladius ziemlich gerade sich fortsetzt. Die Fahnenpartien, die innerhalb dieser Verdickungen liegen, zeigen eine feine schräge Streifung, die mit der Anterolateralkante der Fahne parallel läuft. An der Aussenseite dieser liegt die Marginalarea, welche parallele Dichtungen zeigt. An der Spitze des Gladius findet sich ein ganz flacher Konus mit verdickter Ventralwand.

Die Leuchtorgane zerfallen in Augenorgane und in Ventralorgane. Die ersteren auf dem ventralen Rande des Bulbus in der Bogenreihe, neun in Zahl. Die randständigen, von denen das hintere etwas entfernt von dem vorletzten steht, doppelt so gross als die anderen. Die Organe auf der ventralen Fläche des Mantels stehen an dem vorderen ein-drittel Teile, in etwa acht Streifen von je zwei alternierenden Reihen, die Marginal-

streifen unregelmässig, eine Reihe von Organen auf dem Rand der Mantelöffnung. Auf dem hinteren Zwei-drittel der ventralen Fläche des Mantels verlieren die Organe ihre streifenartige Anordnung und verteilen sich ziemlich dicht neben einander. Auf der Ventralfläche des Trichters finden sich vier Streifen von je zwei bis drei Reihen. Auf der Ventralseite des Kopfes finden wir fünf Reihen; eine mediane Reihe, die gleich von dem vorderen Ende der Trichtergrube beginnt und sich in die Innenfläche des vierten Armes fortsetzt; zwei laterale, eine innere und eine äussere, wovon die erstere, die zunächst die Trichtergrube flankierende, sich in der Aussenreihe der Ventralfläche des vierten Armes fortsetzt. Die äussere Reihe fängt in der Nähe der ersten Längsfalte des Halses an und setzt sich in dem äusseren ventralen Rande des Schwimmsaumes des vierten Armes fort. Auf der ventralen Seite der Augenöffnung liegt diese Reihe gerade über dem Augenorgane. Eine Reihe findet sich auf dem hinteren und ventralen Rand der Augenöffnung. Von dem Vorderrand der Augenöffnung, gleich von dem Dorsalrand des Sinus, verläuft eine Reihe an dem ventralen Aussenrande des dritten Armes entlang. Vereinzelte Organe findet man auch auf der Dorsalseite des Mantels.

Die Kiefer sind wie gewöhnlich gestaltet. Das Rostrum des Oberkiefers ist schlank, die Rostralfügel nicht gross, die Basalfügel gut entwickelt. Der Unterkiefer wie gewöhnlich mit kräftigem Rostrum, grösserem Rostralfügel und mit Kehllamellen, welche nicht grösser sind als die Rostralfügel.

Die Radula zeigt einen ganz einfachen Bau und stimmt ungemein mit der von *Thaumatolampus* CHUN's überein. Jede Zahnreihe besteht wie bei dieser Gattung aus sieben Zähnen, die in Mittelzähne, Seitenzähne und Randzähne sich unterscheiden lassen, und die Zahnformel läuft wie bei jener Gattung: 3,2,2,1,2,2,3. Der Randzahn, der am längsten ist, misst etwa doppelt so lang wie der Mittelzahn; seine Basis ist aber weniger breit wie dieser, und ist etwas gebogen, wie gewöhnlich. Der Mittelzahn sitzt auf der ovalen, die Seitenzähne auf der quadratischen Basalplatte. Jener ist etwas grösser als der innere Seitenzahn, wird aber von dem äusseren an Länge übertroffen.

Das Männchen ist noch nicht bekannt. Eine Anzahl von Spermato-  
phoren sitzen an der dorsalen Seite des Halses unter dem Mantel dicht



hinter dem Nackenknorpel in allen den fünf Weibchen, die wir beobachten konnten. Sie heften sich sowohl an der ventralen Seite des Mantels als an der Dorsalfläche des Leibes an.

Farbe in Formalin gräulich-violettrot, ein dunkler Streifen auf der Mitteldorsallinie über die Rhachis des Gladius, welcher von der Farbe der letzteren verursacht ist. Die Flossen heller gefärbt. Die Buccalhaut dunkelviolett.

Fundort: Bucht von Toyama, japanisches Meer.

Bekanntlich ist bis jetzt nur eine einzige Art von der Gattung *Enoploteuthis* bekannt, *Enoploteuthis leptura* LEACH, welche von der Küste Westafrikas stammt. Nach PFEFFER<sup>3</sup>, dem wir einen zusammenfassenden Bericht über diese Art nach ORBIGNY's Beschreibungen und Figuren verdanken, soll dieselbe aber sehr mangelhaft beschrieben sein, obwohl sie in grossen Museen in London und Paris vertreten ist. Das rührt vielleicht daher, dass die Exemplare in diesen Museen nicht in befriedigendem Zustande sich befinden. Allerdings gibt CHUN<sup>4</sup> eine recht schöne Abbildung von einem Männchen und von einer Tentakelkeule dieser Art in seiner bekannten Arbeit über Oegopsiden, und verspricht eine Beschreibung dieser Art, die wir in kurzer Zeit erwarten dürfen, so dass wir uns noch genauer und gründlicher über die Art werden orientieren können. Obgleich wir ORBIGNY's Arbeit nicht besitzen, so können wir jedoch aus PFEFFER und CHUN schliessen, dass unser Tier zu der Gattung *Enoploteuthis* gehört und eine neue Art derselben representiert. Die folgenden Punkte dürften als Unterscheidungsmerkmale beider Arten hervorgehoben werden:—

*Enoploteuthis leptura*:

1) Die Flosse wird von einem Fünftelteil des hinteren Mantelendes überragt.

*Enoploteuthis chunii*:

1) Die Flosse wird von einem Sechstelteil des hinteren Mantelendes überragt.

<sup>3</sup> GEORG PFEFFER: Die Cephalopoden der Plankton-Expedition: Zugleich eine monographische Übersicht der Oegopsiden Cephalopoden. Ergebnisse der Plankton-Expedition der Humboldt-Stiftung. Bd. II. F. a. 1912. <sup>4</sup>CARL CHUN: Die Cephalopoden. I. Teil: Oegopsida, Wissenschaftliche Ergebnisse der deutschen Tiefsee-Expedition auf dem Dampfer Valdivia 1898-99. 1910.



2) Die hinteren Basalecken der Flosse etwas eingezogen.

3) Die Längenausdehnung der Flosse ist zwei und einviertelmal in der Querausdehnung enthalten.

4) Der Kopf ist breiter als die Mantelöffnung, in seinem Augenteil kugelig aufgetrieben.

5) Die Arme sind lang, die längsten erreichen die Länge des Mantels<sup>5</sup>.

6) Sechs Längsreihen von Leuchtorganen auf der Ventralfläche des Kopfes.<sup>6</sup>

2) Die hinteren Basalecken der Flosse nicht eingezogen, sondern allmählich an den Seiten des hinteren Mantelendes endigend.

3) Die Längenausdehnung der Flosse ist ein und einviertelmal in der Querausdehnung enthalten; die Flosse ist also verhältnismässig viel breiter als lang.

4) Der Kopf ist schmaler als die Mantelöffnung, in seinem Augenteil nicht aufgetrieben.

5) Die Arme sind mässig lang, die längsten erreichen nicht die Mantellänge.

6) Fünf Längsreihen von Leuchtorganen auf der Ventralfläche des Kopfes.

Die hier angegebenen Charaktere von *Enoploteuthis leptura*, welche PFEFFER zwar nicht nach eigenen Beobachtungen angegeben hat, könnten vielleicht nicht als eindeutig betrachtet werden, da die Beobachtungen von ORBIGNY und FERUSSAC schon vor langer Zeit gemacht wurden, welche manche wichtige Punkte, wie z. B. die Beschaffenheit und die Anordnung der Haken und Näpfe auf den Armen und Tentakeln ganz unberücksichtigt gelassen oder sehr schlecht angegeben haben.<sup>7</sup> Es ist aber hervorzuheben, dass die Verschiedenheiten, die ich hier zwischen den beiden Arten

<sup>5</sup> Es ist hier zu bemerken, dass nach der Abbildung CHUN's von einem Männchen der längste Arm desselben etwa Zweidrittel der Mantellänge misst.

<sup>6</sup> Aus der Abbildung CHUN's und aus der Beschreibung von PFEFFER über dieselben. C. CHUN l.c. Taf. XI. Fig. 5. 3. G. PFEFFER l.c. pp. 762.

<sup>7</sup> Allerdings kann man sich an der Abbildung CHUN's ziemlich gut über diesen Punkt orientieren, wie PFEFFER auch anerkannt hat. Dies bezieht sich aber nur auf das Männchen allein.

angegeben habe, uns berechtigen, unsere Art von der atlantischen zu trennen. Ganz überflüssig ist es vielleicht hier zu bemerken, dass der Zweifel PFEFFER'S über die Identität der Gattungen *Enoplateuthis* und *Abralia* unberechtigt ist, nachdem CHUN nach einer erneuten Untersuchung von *E. leptura* die Realität der Gattung nachgewiesen hat, womit auch PFEFFER'S übereinzustimmen scheint. Die paarig-symmetrische Anordnung der Leuchtorgane auf dem Mantel, sowie das Fehlen der grossen Leuchtorgane auf der Spitze des Ventralarmes sind zur Genüge konstatiert, eben durch CHUN und durch unsere neue Art.

### ERKLÄRUNG DER ABBILDUNGEN.

Sämtliche Figuren mit Ausnahme der Figuren 1, 7, 9, 10, 10a, 11a, und 14, sind von Herrn K. Yokoyama unter der Oberaufsicht des Verfassers nach der Natur ausgeführt worden.

#### TAFEL XXXVIII.

*Enoplateuthis chunii* C. ISHIKAWA.

Fig. 1. Photographische Aufnahme eines Weibchens. Fig. 1a, Dorsalansicht; Fig. 1b, Ventralansicht. Nat. Grösse.

Fig. 2. Oralansicht.  $\frac{1}{2}$  nat. Gr.

Fig. 3. Dieselben mit dem Buccaltrichter geschlossen.  $\frac{2}{3}$  nat. Gr.

Fig. 4. Ventralansicht des linken Auges mit Augenleuchtorganen.  $\frac{2}{3}$  nat. Gr.

Fig. 5. Trichter geöffnet um die Trichterorgane zu veranschaulichen.  $\frac{2}{3}$  nat. Gr.

Fig. 6. Kopf mit dem vorderen Teil des Mantels geöffnet, und schräg von der linken Seite gesehen, um die angehefteten Spermatophoren zu zeigen.  $1\frac{1}{2}$  mal vergrössert.

#### TAFEL XXXIX.

*Enoplateuthis chunii* C. ISHIKAWA.

Fig. 7. Rechter Tentakel. Zeiss Objectiv a\* mit Kompensationsokular 2.

Fig. 8. Rechter Ventralarm.  $3\frac{1}{2}$  mal vergrössert.

Fig. 8a. Spitze desselben schräg von der äusseren Seite gesehen, um eine Reihe von Leuchtorganen zu zeigen.  $\frac{2}{3}$  nat. Gr.

\* G. PFEFFER l.c. pp. 762.

- Fig. 9. Tentakelnapf. Zeiss Objectiv B, Kompensationsokular. 2.  
 Fig. 10. Armpf. Zeiss Objectiv B, Kompensationsokular 2.  
 Fig. 10a. Längsschnitt eines Armpfes. Zeiss Objectiv D, Kompensationsokular 2.  
 Fig. 11. Napf des Karpalpolsters. Zeiss Objectiv B, Kompensationsokular 2  
 Fig. 11a. Schnitte desselben. Zeiss Objectiv D, Kompensationsokular 2.  
 Fig. 12. Oberkiefer von der Seite.  $\frac{5}{4}$  nat. Gr.  
 Fig. 12a. Derselbe, Ventralansicht.  $\frac{5}{4}$  nat. Gr.  
 Fig. 13. Unterkiefer von der Seite.  $\frac{5}{4}$  nat. Gr.  
 Fig. 14. Radula. Zeiss Objectiv B, Kompensationsokular. 2.  
 Fig. 15. Nackenknorpel.  $2\frac{1}{2}$  mal vergrößert.  
 Fig. 16. Rechter Trichterknorpel.  $2\frac{1}{2}$  mal vergrößert.  
 Fig. 17. Mantelknorpel; man sieht einige Spermatophoren unten auf der Figur.  
 $2\frac{1}{2}$  mal vergrößert.  
 Fig. 18. Gladius, Dorsalansicht.  $\frac{2}{1}$  nat. Gr.  
 Fig. 18a. Derselbe, Seitenansicht.  $\frac{2}{1}$  nat. Gr.  
 Fig. 18b. Querschnitt desselben durch das Anteriodrittel.  $\frac{4}{1}$  nat. Gr.  
 Fig. 18c. Konus des Gladius. Ventralansicht.  $\frac{4}{1}$  nat. Gr.  
 Fig. 18d. Umriss des Konus von der linken Seite.  $\frac{4}{1}$  nat. Gr.
-





Fig. 2.

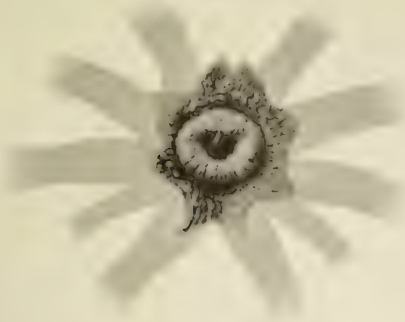


Fig. 3.



Fig. 1a.



Fig. 1b.



Fig. 4.



Fig. 5.



Fig. 6.

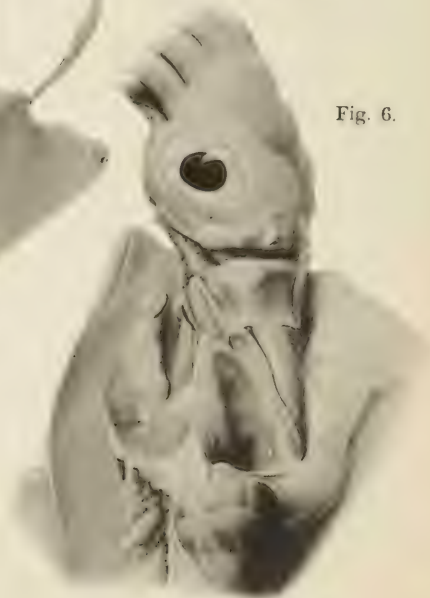




Fig. 7.



Fig. 18b.



Fig. 18a.



Fig. 11.

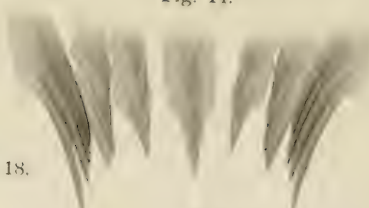


Fig. 18.



Fig. 15.

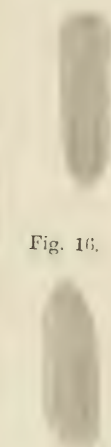


Fig. 12.



Fig. 12a.

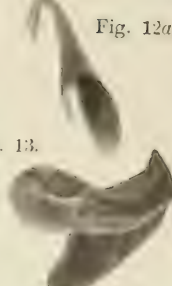


Fig. 16.



Fig. 13.



Fig. 17.



Fig. 11a.

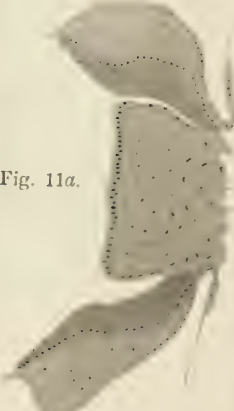


Fig. 8a.

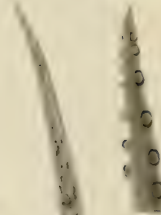


Fig. 8.

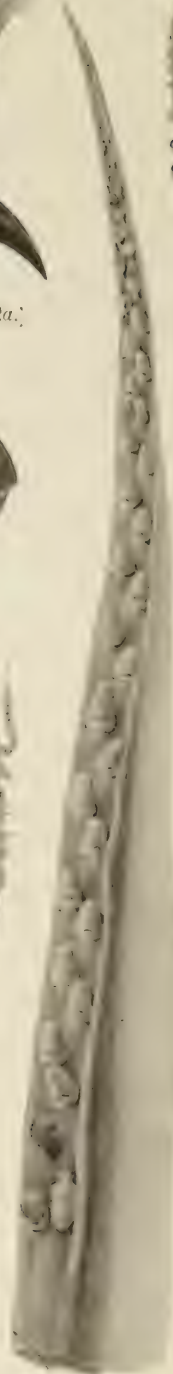


Fig. 9.



Fig. 18c.



Fig. 18d.



Fig. 10.



Fig. 11.



Fig. 10a.







# Note on the Eels of Japanese, Corean, Formosan and adjacent Waters.

BY

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With five Tables and Plates XL, XLI, and XLII.

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The identification of the species of *Anguilla* occurring in the Japanese and Formosan waters appears to be in great confusion. TEMMINCK and SCHLEGEL<sup>1</sup> in their great work on the Fishes of Japan have recognized our common eel as a new species and described it under the name of *Anguilla japonica*. GÜNTHER<sup>2</sup> in his well known Catalogue has identified it with the American, *A. bostoniensis*. In a Preliminary Note on the Fishes of the Lake Biwa, ISHIKAWA<sup>3,4</sup> advanced the view that the two well known species of eels, the *bostoniensis* and the *vulgaris* might be identical, since by the examination of the Japanese eels he found some to correspond exactly with the description of the former given by GÜNTHER, while some resemble that of the latter, and so he ascribed our common eel to the *A. vulgaris*. Later on, he<sup>5</sup> took measurements of some eighty specimens of eels obtained from different localities of the main Islands and of Sikoku, and found that, by such measurements, fifty nine specimens out of eighty resemble *vulgaris*, twelve resemble *bostoniensis*, while nine stand between the two. A similar con-

1. VON SIEBOLDT :—Fauna Japonica, Poiss. P. 258, Pl. 113. fig. 2.

2. GÜNTHER :—Catalogue of Fishes. Vol. VIII.

3. C. ISHIKAWA :—A preliminary Note on the Fishes of the Lake Biwa. Zool. Magazine Vol. VII, 1895.

4. C. ISHIKAWA :—Preliminary Catalogue of Fishes in the Collection of the Nat. Hist. Department, Imp. Museum. Tôkyô, 1897.

5. C. ISHIKAWA :—On the Variation of the proportional Lengths of the Head, etc. as to the total Length in our Common Eel. Annot. Zool. Jap. Vol. II. 1898.

elusion as to the identity of the two species was reached by M. C. DARESTE<sup>6</sup>, who, however, did not take our eels into consideration.

In 1901, D. S. JORDAN and J. O. SNYDER<sup>7</sup> published a Preliminary Check-List of the Fishes of Japan, in which they mention only a single species, *Anguilla japonica*, for our eels, the description of which is given by the same authors<sup>8</sup> in volume XXIII of the Proceedings of the United States National Museum. In his Figures and Descriptions of the Fishes of Japan TANAKA<sup>9</sup> gives also the same name for our eels, and in the joint work by D. S. JORDAN, S. TANAKA and J. O. SNYDER<sup>10</sup>, recently published, the same is repeated.

Now this holds good as far as it concerns the ordinary type of our common eel. The difficulty, however, comes in, when JORDAN, SNYDER and TANAKA put the *ô-unagi* (giant eels) and *kanikui* (crab-eaters), both of which we identify with *A. mauritiana*, together with our common eel into one and the same species, that of *A. japonica*. Although TANAKA<sup>11</sup> does not mention this in his work in 1912, he refers to the paper of JORDAN and SNYDER in the Proc. U. S. Nat. Mus. in which these authors consider *A. bengalensis* and *A. mauritiana* given in the Preliminary Catalogue of ISHIKAWA<sup>12</sup> as synonymous with *A. japonica*. Lastly a species described by D. S. JORDAN and B. W. EVERMANN<sup>13</sup> under the name of *A. remifera* may be accounted as an extreme variety of *A. japonica*, as will be seen in the sequel.

It will thus be seen that all the eels occurring in our waters have been placed under TEMMINCK and SCHLEGEL'S *A. japonica* without any closer examination of the specimens. It is therefore quite necessary that a closer examination of the eels of our waters be carried out to a much greater

6. Comptes-rendus of Academy of Science, Paris.

7. D. S. JORDAN and J. O. SNYDER:—A Preliminary Check-List of the Fishes of Japan. Annot. Zool. Jap. 1901.

8. Proc. U. S. National Museum. Vol. XXIII.

9. S. TANAKA:—Figures and Descriptions of the Fishes of Japan. Vol. IX. 1912.

10. A Catalogue of Fishes of Japan. Journ. Coll. Science, Tokyo Imp. Univ. Vol. XXXIII. 1913. p. 76.

11. TANAKA: l. c.

12. ISHIKAWA: l. c.

13. D. S. JORDAN and B. W. EVERMANN:—Notes on a Collection of Fishes from the Island of Formosa. Proc. U. S. Nat. Mus. Vol. XXV. p. 325, 1902.

extent than before, since the eel question forms one of our most interesting subjects both in ichthyology and in fishery. For this reason, the authors began to make a tolerably extended examination of the specimens of eels mostly obtained at the Tokyo market, but those from the Bonin Islands, the Island of Formosa, as well as those kept in the Imperial Museum and the Fishery School at Fukagawa were also examined. For their liberality in lending us their valuable specimens the authors have to thank the authorities of these institutions. Thanks are also due to Mr. Y. WAKIYA for his valuable aid in many ways during the progress of the work.

In the following pages are described:—

- I. The Common Eel of the principal Islands of Japan.
- II. The Corean Common Eel.
- III. The Formosan Common Eel.
- IV. *Anguilla mauritiana* BENNETT.
- V. *Anguilla sinensis* (?) McCLELLAND.

## I. On the Common Eel of the principal Islands of Japan.

A large number of the common eels of the principal Islands of Japan, Honsyû, Kyûsyû, Sikoku and Hokkaidô, were examined as to the proportional lengths of the head etc. to the different parts of the body, the structures of the mandibular and maxillary bands of teeth, and the numbers of the vertebrae. The number of specimens examined amount in most cases up to one hundred. Only where the examination was made difficult, owing to the state of preservation of the animals, a lesser number was used, the exact number of materials used for the examination of different parts of the bodies being given in the accompanying table (Table I).

1) *Lengths of the head etc. in percentage of the total length.* The length of the head varies from 10.77 to 13.82; the distance from the tip of the snout to the origin of the dorsal fin, from 26.51 to 34.14; the distance between the origin of the dorsal fin and the gill-opening, 15.09 to 20.81; the distance between the vent and the gill-opening, from 25.43 to 30.17; the distance between the commencements of the dorsal and anal

fins, from 7.03 to 12.67; the length of the pectoral fin, from 2.71 to 5.56; length of the upper jaw, from 2.64 to 3.94; length of the snout, from 1.76 to 2.63; diameter of the eye, from 0.60 to 1.47; interorbital space, from 1.10 to 2.37; height of the body in front of the anus, from 4.51 to 5.88 in percentage of the total length.

These numbers show the variations of different parts of the bodies standing at both the extremities given in percentage of the total length. But as a part of the body, which in one case represents an extreme minus or plus variation, does not necessarily mean that another part of the body of the same individual presents also the same variations, it is necessary to take proportional measurements of these parts of the body contained in the total length etc., as for instance the length of the head in the total length, in the distance between the origin of the dorsal fin and the gill-opening, etc. etc.

2) *Lengths of the head etc. contained in the total length etc.* The length of the head is contained  $7\frac{3}{31}$  to  $9\frac{1}{4}\frac{3}{8}$  in the total length,  $1\frac{8}{45}$  to  $1\frac{4}{5}\frac{3}{5}$  in the distance between the origin of the dorsal fin and the gill-opening,  $1\frac{2}{7}\frac{4}{7}$  to  $2\frac{3}{5}\frac{5}{9}$  in the distance between the vent and the gill-opening; the distance between the commencements of the dorsal and anal fins is contained  $\frac{5}{5}\frac{2}{7}$  to  $1\frac{1}{1}\frac{1}{7}$  in the head; the distance from the tip of the snout to the origin of the dorsal fin is contained  $2\frac{1}{1}\frac{5}{5}\frac{7}{9}$  to  $3\frac{1}{1}\frac{9}{2}\frac{5}{3}$  in the total length; the length of the pectoral fin is contained  $2\frac{1}{1}\frac{1}{1}$  to  $3\frac{6}{4}$ ; the length of the snout,  $4\frac{7}{5}$  to 7; and the length of the upper jaw,  $3\frac{1}{8}$  to  $4\frac{7}{1}\frac{7}{2}$  in the head; the diameter of the eye is contained  $1\frac{2}{5}$  to 3 in the snout, and 1 to  $2\frac{3}{4}$  in the interorbital space; the height of the body in front of the anus is contained  $17\frac{3}{1}\frac{3}{4}$  to  $22\frac{1}{5}$  in the total length.

3) *Average lengths of the head etc. in percentage of the total length.* The length of the head is 12.35; the distance between the origin of the dorsal fin and the gill-opening is 18.19; the distance between the vent and the gill-opening is 27.20; the distance between the commencements of the dorsal and anal fins is 9.76; length of the pectoral fin is 4.01; length of the upper jaw is 3.24; length of the snout is 2.16; diameter of the eye is 1.02; interorbital space is 1.92; height of the body in front of the anus is 5.21 in percentage of the total length.



4) *The ratio of the præanal<sup>14</sup> and postanal<sup>15</sup> parts.* The ratio of the præanal and postanal parts varies from 1:1.35 to 1:1.71; and the average length of the præanal part to that of the postanal part is 1:1.53.

5) *The number of the pectoral fin rays.* One hundred and eighteen specimens were examined for this purpose. It was found that the number of the pectoral fin rays varies from 14 to 19, the mean number being 16.87. In most specimens, the number is 17.

6) *The number of the branchiostegal rays.* In one hundred specimens the number of the branchiostegal rays varies from 9 to 13, the mean number being 10.82. Most specimens have 11 rays.

7) *The number of the vertebrae.* The total number of the vertebrae counted, varies from 112 to 119, of which the præcaudal portion counts 42 to 47, while the caudal portion, 68 to 76. The formula of the vertebrae in average is as follows:—

$$43.67 + 71.98 = 115.65$$

The average number of vertebrae recently given by JOHS. SCHMIDT<sup>16</sup> obtained from two-hundred and two specimens of *A. japonica* is 115.876; and that given by MARUKAWA<sup>17</sup>, from ninety-one specimens is 116.29. Thus both these numbers correspond almost exactly with the above given number taken from one hundred of our specimens, the frequency curve in all cases being nearly similar, as will be seen from the following table.

THE NUMBER OF VERTEBRÆ. THE NUMBER OF INDIVIDUALS.

	AUTHORS'.	SCHMIDT'S.	MARUKAWA'S.
119.....	1	3	1
118.....	8	17	3
117.....	18	43	21
116.....	28	63	50
115.....	23	40	15
114.....	18	23	1

14. Distance from the tip of the snout to the vent.

15. Distance from the tip of the caudal fin to the vent.

16. JOHS. SCHMIDT;—Zur Unterscheidung einiger Süßwassermaarten. Der Fischerbote. V. Jahrgang. Nr. 11. 1913.

17. MARUKAWA:—Suisan-Kwai Ho (The Journal of the Fishery Society of Japan). No. 366. 1913.

113.....	3	7	—
112.....	1	1	—
The total number of specimens			
observed	100	202	91
The mean number of vertebræ			
	115.65	115.876	116.25

8) *The coloration.* It is a well known fact that variations of color often occur among the individuals of our common eel, even among those that are found in one and the same locality. A form with many black spots scattered all over the body, and known by the name of *goma-unagi* or spotted eel is considered by fishermen and fishmongers as a species distinct from the ordinary eel. It is, however, nothing more than a color variation, as no other distinctive characters except this peculiar coloration can be found, and the intermediate forms between the usual colored ones and the spotted are not at all seldom.

9) *The shape of the tail end.* The shape of the tail end is quite variable, but can generally be grouped into the following three:—

- a) The marginal end roundish.
- b) The marginal end somewhat pointed.
- c) The marginal end sharply pointed.

Of these three most of the individuals can be placed under the second form.

10) *The form of the pectoral fin.* The pectoral fin varies very much in form, but can also be classified into three forms:—

- a) The marginal end nearly round; the length nearly equals to its width.
- b) The marginal end sharply pointed; the length more or less greater than the width.
- c) The marginal end sharply pointed; the length decidedly greater than the width.

Of the above three forms, the second is the most common.

11) *The shape of the snout.* The shape of the snout varies much in both the sexes; but is generally broader in the females than in the males. This, however, can not be considered as a definite character, since we often find males in which the snout is broader than in the females of the same size.

12) *The Relative position of the angle of the mouth to the eye.* In general, the angle of the mouth extends to the vertical from the hind margin of the eye. This, however, can not be looked upon as a definite character, for we often find specimens in which the angle of the mouth extend to beyond the hind margin of the eye, or ends in front of it.

13) *The bands of teeth.* In the eels the bands of teeth are usually restricted to three regions of the maxilla, the mandible, and the vomer. A specimen caught in a pond of the Fishery School at Fukagawa, Tokyo (so-called Imperial Fisheries Institution), shows a distinct band of teeth on each side of the palate situated near the posterior end of the band of teeth of the upper jaw. These bands are very small consisting of about seven teeth each.

14) *The longitudinal groove in the maxillary and mandibular bands of teeth.* The statement with regard to teeth in the original description of our common eel given by TEMMINCK and SCHLEGEL<sup>18</sup> in *Fauna Japonica* is quite simple. It is nothing more than the following:—

“Les dents ne diffèrent pas de celles de l'espèce commune.”

So far as known, GÜNTHER<sup>19</sup> was the first who described the presence of a longitudinal groove in the mandibular band<sup>20</sup> of teeth in the eels. In his valuable Catalogue of Fishes he recognizes this fact to be an important specific character of *Anguilla*, and gives a pretty good description of the mandibular band of teeth in every species he mentioned. According to this description there is no longitudinal groove present in the mandibular band of teeth, neither in *A. vulgaris* nor in *A. bostoniensis*, to the latter of which he put our *A. japonica* as a synonym.

Although GÜNTHER did not make any close examination of the dental bands in our common eel, it is not to be doubted that he places it to belong to those species in which the longitudinal groove is absent in the mandibular band. Closer examination, however, reveals us the presence of a distinct groove in both of the mandibular and the maxillary bands.

18. VON SIEBOLDT: l. c.

19. GÜNTHER: l. c.

20. GÜNTHER does not mention anything about the maxillary bands of teeth which, as will be seen later, are of nearly the same importance as those of the mandibular bands.

The band is divided in each case by a groove into two strips, the outer of which consists of two rows of teeth for its greater portion, the inner row having much larger teeth than the outer. The inner strip consists mostly of a single row of smaller teeth which are nearly of the same size as the outermost teeth of the outer strip. Both in outer and inner strips the number of the rows increase and become more or less irregular near the front end, where the groove also becomes obscure.

Lastly, the size of the teeth of the vomerine band is similar to those of the jaws, but they become smaller posteriorly, while the band itself is broader, but slightly shorter than that of the maxillary, and tapers behind.

#### Considerations as to the specific characters of our common eel.

Although the number of specimens observed by the authors are too few to draw any decisive conclusion as to the specific distinction of our common eel, the characters given above, as well as those given by other authors, when taken together, are enough to make us conclude that our species is distinct from other forms of eels hitherto known, and the specific name of *Anguilla japonica* given by TEMMINCK and SCHLEGEL can best be applied to this form, although his description is, as might be expected, not enough to distinguish it from other species of *Anguilla*. The difficulty comes in, however, if we try to distinguish it from such allied forms as *A. vulgaris*, *bostoniensis* or *rostrata*, from all of these it is sometimes very difficult or even impossible to draw a clear line of demarcation, as many intermediate forms link them together on all sides.

Of the distinctive characters in which *A. japonica* differs, however, from its allies may be mentioned the following:—

- 1) The length of the head contained in the total length; 2) the position of the origin of the dorsal fin in the body; 3) the length of the upper jaw contained in the head; 4) the proportion of the distances between the origins of the dorsal and anal fins to the length of the head; 5) the ratio of the præanal and postanal parts; 6) the proportion of the height of the body in front of the anus to the total length; 7) the total



number and the formula of the vertebrae; 8) the structure of the bands of teeth in jaws and vomer; 9) the relative position of the angle of the mouth to the eye.

If we now compare the parts of the bodies of *A. vulgaris* and *A. bostoniensis* given by SETH E. MEEK<sup>21</sup>, and the mean number of the vertebrae obtained from two thousand seven hundred and seventy-five specimens of *A. vulgaris*, and from three hundred and sixty-one specimens of *A. bostoniensis* observed by JOHS. SCHMIDT<sup>22</sup>, with those taken from the average of one hundred specimens of *A. japonica* given above, we will find that in *A. japonica*, the length of the head is shorter than in *A. bostoniensis* (12.50%), and still shorter than in *A. vulgaris* (13.20%); the distance from the tip of the snout to the origin of the dorsal fin is shorter than in *A. bostoniensis* (33.50%), and slightly longer than in *A. vulgaris* (30.50%); the distance between the commencements of the dorsal and anal fins is nearly equal to that in *A. bostoniensis* (9.75%), and distinctly shorter than in *A. vulgaris* (13.67%); the mean number of the vertebrae is about eight more than in *A. bostoniensis* (107.116), and about one in *A. vulgaris* (114.728).

As, however, the number of the specimens of *A. vulgaris* and *A. bostoniensis* observed by SETH E. MEEK is not known, it is perhaps not quite safe to draw any conclusion from such a comparison. For this reason the above comparison is to be looked upon as giving only some hints as to the differences existing between these species of *Anguilla*.

## II. On the Corean common eel.

According to the observations on four specimens obtained from Keijō (Seoul), Fusan and Heijō, the Corean common eel can be safely identified with *A. japonica* TEMMINCK et SCHLEGEL, as has been suggested by H. MARUKAWA, and the measurements of the above four specimens, as will be seen from the table (Table III), exactly correspond with those of this species. It may be mentioned here in this connection, that the common European *A.*

21. SETH E. MEEK:—Bull. U. S. Fish Comm. 1883. This work was not accessible; the reference is taken from the foot-note given by Jordan and Evermann, Fishes of North and Middle America.

JOHS. SCHMIDT: l. c.

*vulgaris* (*A. anguilla*) is stated by BERG<sup>23</sup> to occur in Corea. This can only be determined by actual observations of his specimens, since our specimens do not show any sign of their being synonymous with *A. vulgaris*.

### III. On the Formosan common eel.

Forty-seven individuals of eels from the Island of Formosa were examined, and compared with our Japanese forms.

The comparison revealed no distinctive characters of any importance between them. On the average it shows that in the former the length of the head, the distance from the gill-opening to the origin of the dorsal fin, the distance from the tip of the snout to the origin of the dorsal fin, the distance of the gill-opening from the vent, the distance between the origins of the dorsal and anal fins, the length of the pectoral fin, the diameter of the eye, the interorbital space, the height of the body in front of the anus are somewhat greater, while the length of the snout, the length of the upper jaw and the length of the postanal part of the body is more or less smaller; and the mean number of the vertebræ is lesser in the former than in the latter. The tail of the Formosan forms is generally rather more pointed than that of ours. It is, however, quite difficult to ascertain whether these differences do really exist, and even when this is found to be the case, the question still remains whether these are to be regarded as having any specific value. For these reasons the authors are inclined to consider the Formosan common eel only as a local variety of *A. japonica*. In the following table the lengths of the head etc. in percentage of the total length of the Japanese form compared with that of the Formosan are given:—

THE AVERAGE LENGTH OF THE PARTS OF THE BODY AND THE  
MEAN NUMBER OF THE VERTEBRÆ.

	Japanese form.	Formosan form.	Corean form.
The total length.....	110.	100.	100.
The distance from the gill-opening to the origin of the dorsal fin....	18.18	18.41	18.97

23. The paper of BERG was not accessible, but the fact was kindly communicated by Dr. S. Tanaka to the authors.

The length of the head. ....	12.35	12.70	12.28
The distance from the gill-opening to the vent..... ..	27.20	28.45	28.11
The distance from the tip of the snout to the origin of the dorsal fin. ....	30.54	31.11	31.25
The distance between the origins of the dorsal and anal fins. ...	9.76	10.31	10.42
The length of the pectoral fin. ...	4.01	4.77	3.99
The length of the upper jaw.....	3.24	3.20	3.29
The length of the snout.....	2.16	2.14	2.09
The diameter of the eye. ....	1.02	1.11	1.02
The interorbital space.....	1.92	2.06	2.18
The height of the body in front of the anus..... ..	5.21	5.40	5.21
The ratio of the præanal and postanal parts. ....	1:1.53	1:1.47	1:1.48
The number of the vertebræ. ....	115.65	115.57	116.00

Again the number of vertebræ possessed by different individuals of the Formosan and the Japanese eels:—

#### THE NUMBER OF INDIVIDUALS.

Number of vertebræ.	Japanese form.	Formosan form.
119	1	—
118	8	2
117	18	9
116	28	17
115	24	12
114	17	3
113	3	2
112	1	1
111	—	1

Looking at these tables we notice that the various proportions in the two forms nearly correspond with each other; the largest number of individuals with 116 and 115 vertebræ is also found in both forms in nearly the same proportion. The absence of the specimen with 119

vertebrae in the Formosan and the presence of a single individual with 111 which is not met with among the Japanese form, is perhaps to be looked upon only as local variations.

It now remains, in connection with the discussion of the Formosan eel, to consider two species, one given by GÜNTHER<sup>24</sup> as *bostoniensis* from Formosa, and another described by JORDAN and EVERMANN<sup>25</sup> as a new species under the name of *Anguilla remifera*.

The specimens given by GÜNTHER as *A. bostoniensis* are stated to be "half grown specimens from Formosa," and can presumably be referred to *A. japonica*, since the author considers the two forms as one and the same species, as said before.

*A. remifera* is a species described by JORDAN and EVERMANN from a single specimen obtained from Hôkotô, Formosa. It appears, however, that this so-called *remifera* is nothing more than a variety of *A. japonica*; the distinctive specific characters given to it by the authors, that the length of the head is slightly smaller than the distance between the origins of the dorsal and anal fins, and that the pectoral fin is much larger, being 2.17 in the head and rather pointed, are the points which are to be seen in extreme varieties among *A. japonica*. Such varieties are the Nos. 25, 31 and 74 in the Table II of the Formosan *A. japonica* we examined, and which almost exactly correspond with the characters given for *A. remifera*. These individuals can not, therefore, be regarded as an independent species, but only as individuals standing at one end of the numerous varieties occurring among the specimens of *A. japonica*, all the intermediate forms being found between them and the ordinary forms on one side, and on the other side many forms connect these and the varieties standing at the other extreme.

Should therefore *A. remifera* be regarded as a species distinct from *A. japonica*, then all these forms standing at the other extreme end of the series, such as Nos. 1. 6. and 9. 5. in Table I of the Japanese waters must also be considered as a distinct species.

24. GÜNTHER:—l. c.

25. JORDAN and EVERMANN:—l. c.



IV. *Anguilla mauritiana* BENNETT.

In the running waters of the middle and southern provinces of the Japan Islands, as well as in those of the Bonin Islands, there is found a kind of eel which often attains a large size, and of stouter appearance than the ordinary *A. japonica*. These are known by the fisherman as *ô-unagi*, giant eels, or *kanikui*, crab-eaters. On closer examination of the specimens found in our collections, they are found to be a species widely distributed in the East Indian region, and described by BENNETT<sup>26</sup> under the name of *A. mauritiana*. The proportional lengths of the heads etc. taken from five specimens are as follows; the exact measurements being given in the table (Table IV).

The length of the head is contained  $6\frac{1.6}{10.9}$  to  $7\frac{7}{34}$  in the total length,  $\frac{8.5}{10.9}$  to  $1\frac{3}{11}$  in the distance of the gill-opening from the origin of the dorsal fin, and  $1\frac{8.6}{10.9}$  to  $2\frac{7}{33}$  in its distance from the vent; the distance between the commencements of the dorsal and anal fins is longer than the head and the length of the head is contained  $1\frac{7.9}{10.9}$  to  $1\frac{6}{11}$  in it; the distance from the tip of the snout to the origin of the dorsal fin is contained  $3\frac{5}{13}$  to  $4\frac{4}{5}$  in the total length; the length of the pectoral fin is contained  $2\frac{2.0}{3.3}$  to  $3\frac{8}{25}$ , the length of the snout  $4\frac{1}{4}$  to  $4\frac{2.1}{2.2}$ , and the length of the upper jaw  $2\frac{1.9}{3.3}$  to  $2\frac{1.0}{1.7}$  in the head; the diameter of the eye is contained  $2\frac{1.9}{10.9}$  to 3 in the snout, and  $2\frac{2}{9}$  to  $3\frac{2}{3}$  in the interorbital space; the height of the body in front of the anus is contained 13 to  $16\frac{1}{3}$  in the total length; the length of the præanal part to that of the postanal part is 1:1.20 to 1:1.39. The cleft of the mouth lies far beyond the hind rim of the eye. Lips are well developed, the lower jaw is rather projecting. The teeth in the jaws and the vomer are subequal, and villiform; the vomerine band of teeth is scarcely broader and shorter than that of the maxillary, and tapers behind; the teeth becoming smaller posteriorly.

26. BENNETT:—PRO. CONN. Zool. Soc. 1831, p. 138. GÜNTHER: Catalogue of Fishes. Vol. VIII, p. 25. ISHIKAWA; Prelim. Catalogue of Fishes etc. 1897. p. 7. gives it to a specimen of eel from Awa, Sikoku Island, with an interrogation mark, but as his specimen is a stuffed one, we could not identify it with our specimen. JORDAN, TANAKA and SNYDER l. c. appear to deny the existence of the species in Japan or identify it with the common *A. japonica*, since they mention the Japanese name *ô-unagi* and *kanikui* as synonymous with the common *unagi* or *A. japonica*. l. c. 46.

The mandibullary and maxillary bands of teeth are longitudinally divided by a distinct groove into two strips. The outer consists of two or three rows of teeth for its greater portion, the innermost row of which being much larger than others, while the inner strip consists mostly of a single row of smaller teeth which are nearly of the same size as the outermost teeth in the outer strip in which the rows increase and become more or less irregular near the front end.

The color of the specimens preserved in formalin is bluish black, mottled with black; the ventral part of the body pale.

From these as well as from the details given in the table, it will be observed that some individuals do not strictly coincide with the description of *A. mauritiana* given by GÜNTHER. But the deviations are, as will be seen from the table, of minor importance and do not exclude the idea of the identification of these specimens with this species. *A. mauritiana* is, as above mentioned, of wide range, occurring in the East-Indian Ocean and archipelagoes, Formosa, Bonin Islands (Ogasawara), and in waters of the middle and southern Islands of Japan. The differences between this species and *A. japonica* are to be looked for in the number of vertebrae, the position of the dorsal fin, and the relative position of the angle of the mouth and eye.

#### V. *Anguilla sinensis* (?) McCLELLAND.<sup>27</sup>

Among numerous specimens of eels bought in the market of Tôkyô, we found a single individual showing a marked variation from the common *A. japonica*. The examination of external characters, showed it to have a great similarity with the species given by GÜNTHER under the name of *A. sinensis* McCLELLAND, to which we are inclined to place it, although it differs from GÜNTHER's description of the mandibullary bands of teeth, which is stated to have no groove, whereas in our specimen this is quite evident both in mandibullary and in maxillary bands.

The specific characters of our specimen will be given as follows:—

Vert. 43+55; p. 17; Br. 12.

<sup>27</sup>. *Anguilla sinensis*, McCLELL. Calc. Journ. IV. p. 406, tab. 25. fig. 2.

The length of the head is contained  $7\frac{9}{10}$  in the total length,  $1\frac{1}{3}$  in the distance of the gill-opening from the origin of the dorsal fin, and  $2\frac{4}{5}$  in its distance from the vent; the distance between the commencements of the dorsal and anal fins is shorter than the head, and contained  $1\frac{9}{17}$  in the head; the distance from the tip of the snout to the origin of the dorsal fin is contained  $2\frac{10}{11}$  in the total length; the length of the pectoral fin is contained  $2\frac{3}{17}$ , the length of the snout  $5\frac{1}{4}$ , and the length of the upper jaw 4 in the head; the diameter of the eye is contained  $2\frac{7}{10}$  in the snout and 2 in the interorbital space; height of the body in front of the anus is contained  $16\frac{1}{10}$  in the total length; the proportion of the præanal part to that of the postanal is 1 to 1.26. The cleft of the mouth extends to the hind margin of the eye. Lips are rather thin; lower jaw is prominent. The teeth in the jaws and the vomer are villiform, subequal; the vomerine band of teeth tapers behind and is a little broader and shorter than that of the maxillary, the teeth becoming also smaller posteriorly; the mandibular and maxillary bands of teeth are longitudinally divided into two strips by a groove. The outer strip consists mostly of two rows for its greater portion, the inner row of which having much larger teeth than the outer. The inner strip consists mostly of a single row of smaller teeth which are nearly of the same size as the outermost teeth of the outer strip. Both in outer and inner strips the number of the rows increase and become more or less irregular near the front end where the groove also becomes obscure.

The color of the dorsal part is yellowish black; lateral part reddish yellow, ventral white, and the marginal end of the tail is black.

As will be seen, the above description is made from a single specimen and, as well known, it is not quite safe to conclude the specific character of the specimen, especially as the eels belong to such animals which show great individual variations<sup>28</sup>. From the coincidence of external characters of this specimen with the description given by GÜNTHER of *A. sinensis*, we tried to identify it with this species. But as these characters are the

28. JOHNS. SCHMIDT:—l. c. p. 451. rightly remarks on this point as follows:—"Innerhalb der Gattung *Anguilla* ist es ganz unmöglich, durch Untersuchungen von nur einem oder wenigen Individuen eine Art festzulegen, wie das bei vielen anderen Fischen möglich ist."

points which are considered by such authorities as JOHS. SCHMIDT as liable to variability during the individual life of the eel, we would not try to identify it with *sinensis*, if it did not show the great difference in the number of the vertebrae, which as stated above amounts to only 98, whereas in all the allied forms the number is more, and this number is known to belong to such characters of the eel which are not changeable during the life of an individual. Should it therefore be proved not to be identified with *sinensis*, it is tolerably certain that it is not at the same time synonymous with either *vulgaris*, *rostrata* or *japonica*<sup>29</sup>.

From the above it will be seen that three species of *Anguilla* occur in our waters: *A. japonica*, *A. mauritiana* and *A. sinensis* (?). Of these, the first species is the most common, occurring in all waters of the main Island facing the Pacific Ocean, the Islands of Sikoku and Kyûsyû, the Bonin Islands, Hokkaidô, Formosa and Corea. On the Japan sea side of the main Island it occurs only in waters flowing to the sea west of the Noto peninsula, no Montées are found to come up the streams all along the coast of Toyama, Niigata, Akita, and Aomori as far north as the strait of Tugaru. The *mauritiana* occurs, as said before, in the waters of the middle and southern parts of Japan, being found in all the Islands of Izu, and Bonin Islands; but it is not a true Japanese eel, as it is found in all the waters of the Indo-Malay region. It is the *ômagi* and *kanikui* of our fishermen and not synonymous with *A. japonica*, as JORDAN, TANAKA and SNYDER seem inclined to take it. The occurrence of this species in our waters is therefore to be looked upon only as outside stragglers from the tropical sea of Asia. Lastly the species we identified with *sinensis* is, when proved to be a true independent species, a very rare animal in Japan.

The Formosan *A. remifera* described by JORDAN and EVERMANN is to be regarded as identical with *A. japonica*; and the statement of the occurrence of *A. anguilla* or *vulgaris* in Corea is very doubtful, and can only be confirmed by later researches. Lastly, a species of eel which is stated to have been caught in a rapid in Awa, Island of Sikoku, and

29. JOHS. SCHMIDT, for instance, gives the average number for *vulgaris* 114.728, *rostrata* 107.116 and for *japonica* 115.876.



described by D. S. JORDAN<sup>30</sup> under the name of *A. manabei*, is to be reserved for future investigations, since the description is made from only a single specimen, and nothing is known about the number of the pectoral fin rays or of the vertebræ.

30. DAVID S. JORDAN:—Description of *Anquilla manabei*, a new eel from Japan. Proc. U. S. Nation. Museum, Vol. 44, 1913.

## EXPLANATION OF PLATES.

### PLATE XL.

#### *Anquilla japonica*.

Fig. 1. The curves showing the number of branchiostegal rays possessed by one-hundred individuals of the Japanese and forty-seven individuals of the Formosan common eel—*A. japonica*; the black spots within heavy line show the number possessed by the Japanese form, those within the broken line, the Formosan. The figures on the left of the plate show the number of the individuals, those at the bottom the number of branchiostegal rays; in the next column twenty six individuals with ten branchiostegal rays etc.

Fig. 2. The curves showing the number of the pectoral fin rays possessed by one-hundred and eighteen individuals of the Japanese, and forty-seven individuals of the Formosan common eel—*A. japonica*; the black spots within the heavy line show the number possessed by the Japanese form, those within the broken line, the Formosan. The figures on the left of the plate show the number of the individuals, those at the bottom the number of pectoral fin rays.

### PLATE XLI.

#### *Anquilla japonica*.

All the figures are photographic reproductions from nature.

Fig. 1. Side view of the head and the anterior portion of the body in three specimens, showing the relative position of the angle of the mouth and the eye. Fig. 1a, a male with a total length of 445mm. Fig. 1b, a male with a total length of 345mm. Fig. 1c, a male with a total length of 445mm.

Fig. 2. Side view of the head and the anterior portion of the body, showing the variations in the form of the pectoral fin. Fig. 2a, a female individual of 322mm total length. Fig. 2b, a male individual of 350mm. Fig. 2c, a male of 420mm.

Fig. 3. Dorsal view of the heads of three male individuals, showing the variations in their breadth. Fig. 3a, an individual of 423mm; Fig. 3b, 420mm; and Fig. 3c, 355mm.

Fig. 4. Side view of the tail-ends of three individuals, showing the variations in their forms. Fig. 4a, a male with the total length of 430mm; Fig. 4b, a female, 540; Fig. 4c, a female (?), 494mm.

Fig. 5. Two individuals showing the variations of the length of the head. Fig. 5a, an individual with the total length of 380mm; Fig. 5b, 412mm.

Fig. 6. Two individuals showing the variations in the position of the dorsal fin. Fig. 6a, 232mm long; Fig. 6b, 548mm long.

Fig. 7. Two individuals of *A. japonica* from the Main Island, showing the variations of the proportion of the distance between the origins of the dorsal and anal fins as to the length of the head. Fig. 7a, an individual with the total length of 275mm; Fig. 7b, an individual with the total length of 283mm.

Fig. 8. Three individuals of *A. japonica* from Formosa. Fig. 8a, an individual with the total length of 439mm, and almost exactly resembling the form described by JORDAN and EVERMANN under the name of *A. remifera*. Fig. 8b, an individual with the total length of 439mm, in which the head is shorter than the distance from the origin of the dorsal to that of the anal fin. Fig. 8c, an individual in which the head is longer than the distance between the commencements of the dorsal and anal fins, 358mm long.

Fig. 9. A Korean example of *A. japonica*, 457mm long.

Fig. 10. *Anguilla mauritiana*, 430mm long.

Fig. 11. *Anguilla sinensis* (?), 331mm long.

## PLATE XLII.

Figs. 12-18. Outline drawings of different kinds of eels occurring in our waters as compared with those of *A. vulgaris* and *A. bostoniensis*.

Fig. 12. *A. japonica*—Japanese common eel.

Fig. 13. *A. japonica*—Formosan common eel.

Fig. 14. *A. japonica*—Korean common eel.

Fig. 15. *A. mauritiana*.

Fig. 16. *A. sinensis* (?).

\*Fig. 17. *A. vulgaris*.

\*Fig. 18. *A. bostoniensis*.

Fig. 19-22. Sketches showing the bands of teeth of *A. japonica*, *mauritiana* and *sinensis* (?). Fig. 19 and 20, *A. japonica*; Fig. 19a, mandibular band; Fig. 19b, maxillary and vomerine bands. Fig. 20, maxillary and vomerine bands of teeth in another individual in which the palatine bands of teeth are also seen. Twice the natural size.

Fig. 21, *A. mauritiana*; Fig. 21a, mandibular band; Fig. 21b, maxillary and vomerine bands. Natural size.

Fig. 22, *A. sinensis* (?); Fig. 22a, mandibular band; Fig. 22b, maxillary and vomerine bands. Twice the natural size.

\*These figures are reconstructed from the accounts and figures given by various European and American authors, such as Seth E. Meek, D. S. Jordan, Emil Walker and others.

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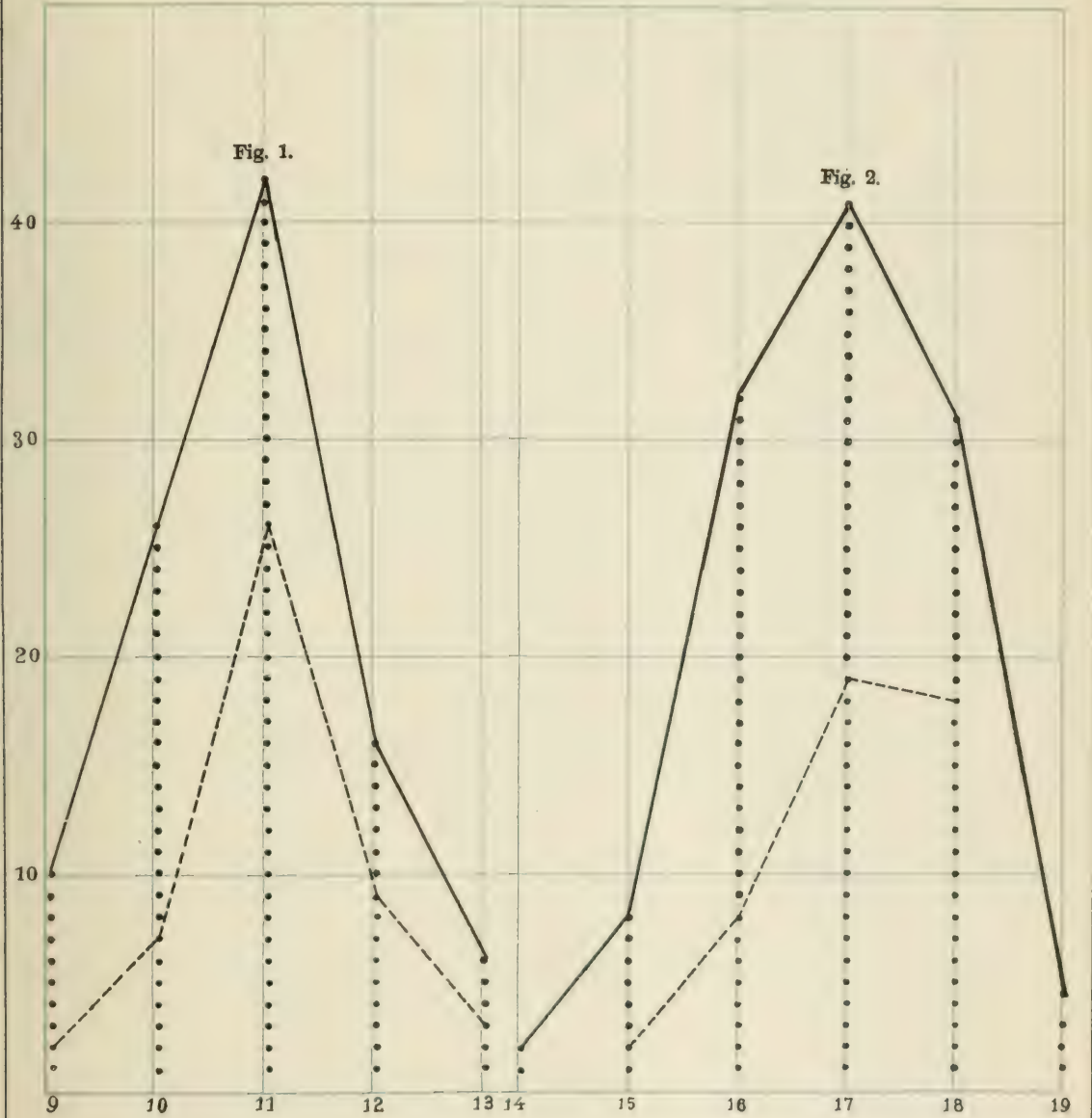






Fig. 7. *a.*



Fig. 7. *b.*



Fig. 8. *a.*

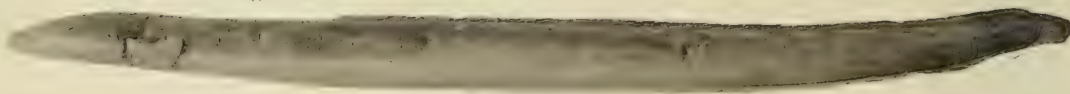


Fig. 8. *b.*



Fig. 8. *c.*

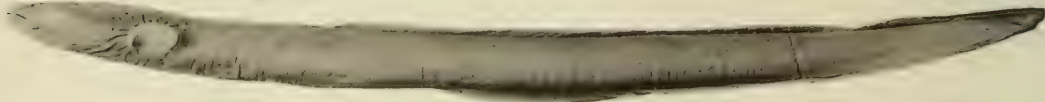


Fig. 9.



Fig. 10.

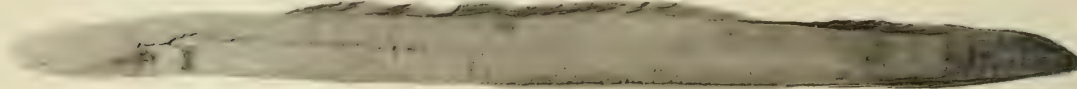
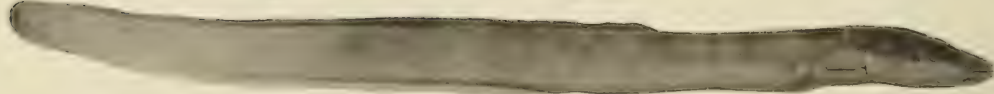


Fig. 11.





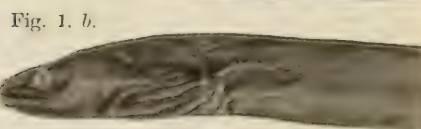
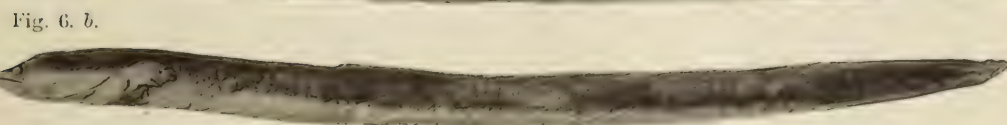
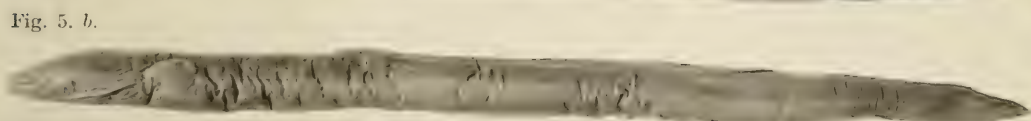
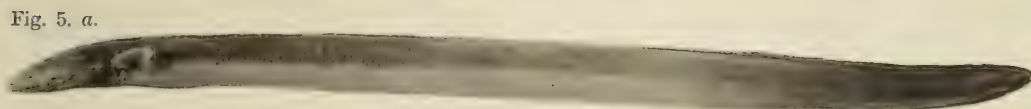
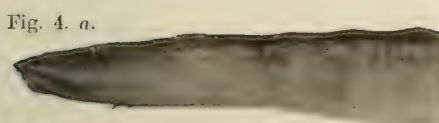




Fig. 12.

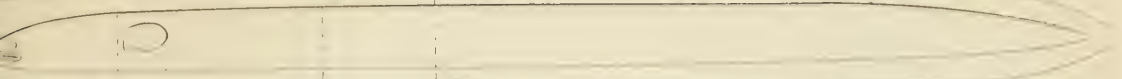


Fig. 13.

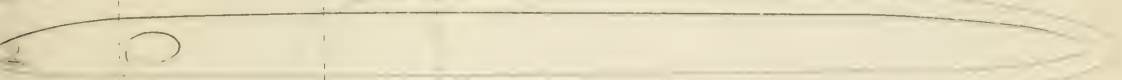


Fig. 14.

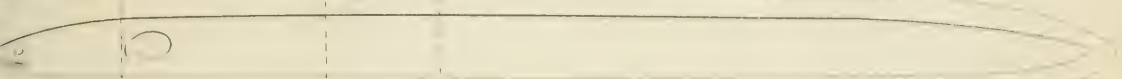


Fig. 15.

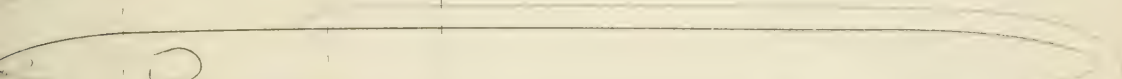


Fig. 16.

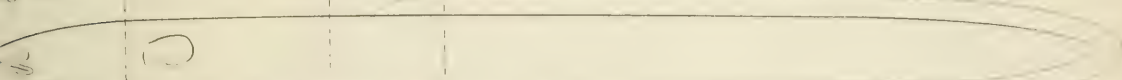


Fig. 17.



Fig. 18.

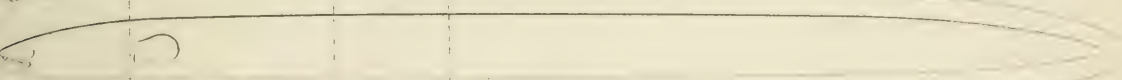


Fig. 19. a.

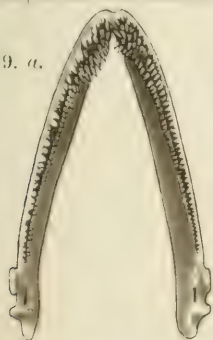


Fig. 19. b.

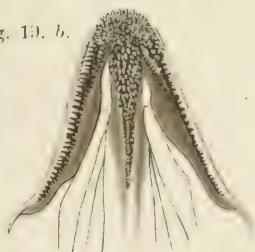


Fig. 20.



Fig. 21. a.

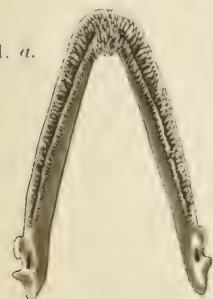


Fig. 21. b.

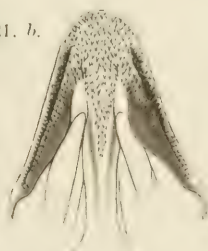


Fig. 22. a.

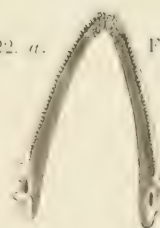


Fig. 22. b.

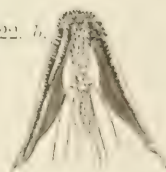






Table 1.\* Japanese Common Eel—*Anguilla japonica* TEMMINCK et SCHLEGEL.



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## Note on a Gigantic Squid obtained from the Stomach of a Sperm Whale.

BY

C. Ishikawa and Yôjirô Wakiya.

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With Plates XLIII & XLIV.

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The description of a gigantic squid here given is made from a specimen in the Fishery station at a small village called Samé belonging to the Prefecture of Aomori, and brought from the station by C. ISHIKAWA, who on his visit there in 1912 found the specimen in a tin box filled with very weak formalin. To the director of the station, Mr. KOIWA, as well as to the Ex-Governor of Aomori Prefecture, Dr. C. TAKEDA, the authors tender their best thanks for their kindness in lending the valuable specimen.

The squid is said to have been found in the stomach of a sperm whale caught in the open sea off the south of the strait of Tugaru during the month of August, 1911. As might be expected, the specimen is not a complete one, having been partly digested. The body was torn into three pieces, consisting of head, mantle, and fin; in all these parts the epidermis is wanting and no traces of the pen, the masticating organs, the eyes, or of the internal organs were to be seen. In the following pages a description is given of the parts as far as it was possible, and by comparing this with the descriptions of similar specimens hitherto given by different authors,\* the systematic position of the specimen is established.

*Mantle*:—The mantle is torn into two pieces, an anterior larger and a posterior smaller portion. The larger portion measures 920 mm in

\* Such as Dall, Verrill, and Thompson.

length; its anterior half is nearly complete, but in the posterior half only the ventral and the left portions remain, while the rest is lost altogether. The foldings of the dermis of the mantle are directed more or less obliquely and transversally, and there is a distinct furrow along the mid-dorsal line of the mantle, which, however, appears to have no direct connection with the development of the pen. The mantle cartilages are simple, represented by longitudinal ridges of about 175 mm, fading out gradually and posteriorly.

The exact length of the mantle can not be made out, but by connecting two pieces by the cut edges which fit tolerably well to each other, we estimated it to be about 1220 mm.

The measurements of the circumference of the mantle at different levels of the anterior larger piece are as follows:—

At the anterior edge of the mantle.....	500 mm.
At a point 60 mm from the mantle edge.....	460 mm.
„ „ „ 100 mm „ „ „ „ .....	440 mm.
„ „ „ 200 mm „ „ „ „ .....	490 mm.
„ „ „ 300 mm „ „ „ „ .....	510 mm.
„ „ „ 400 mm „ „ „ „ .....	520 mm.
„ „ „ 500 mm „ „ „ „ .....	504 mm.
„ „ „ 600 mm „ „ „ „ .....	504 mm.
„ „ „ 700 mm „ „ „ „ .....	440 mm.
„ „ „ 800 mm „ „ „ „ .....	360 mm.
„ „ „ 900 mm „ „ „ „ .....	160 mm.

The posterior smaller piece of the mantle measures 290 mm in length, with a diameter of 35 mm at its anterior end.

From these measurements it will be seen that the general shape of the mantle is evenly conical with the anterior edge somewhat expanded: bulging out a little posteriorly, the greatest breadth being at about  $1/3$  of the length of the mantle from the anterior edge, gradually becoming narrower till about  $3/4$ , whence it suddenly narrows to the posterior end.

*Fins*:—The fins taken together are trapezoidal, the posterior third markedly narrowed and sharply produced. The greatest length of the fin measures 640 mm, the lines attached to the mantle being 610 mm. The



greatest breadth across the lateral angles measures 460 mm. The fins appear not to be quite symmetrical on both sides, the greatest breadth of the left fin lying a little in front of the right.

*Head*.:—The dorsal skin of the head presents a dark violet color. The eye-balls, the buccal apparatus, and cranial cartilages being worn off, we can not give any descriptions of these important parts, except the following points. These are the anterior circular margin of the neck, which in the middle line is produced backward in form of a blunt triangle; the extent of the sinus of the right eye-lid, which ends directly at the base of the third arm; the presence of three longitudinal foldings along the neck, and the absence of the foldings of the nape.

*Siphon*.:—The siphon is conical in shape. It has a large internal valve near its entrance which is overlapped by the dorsal edge of the siphon. The length of the siphon in the mid-ventral line measures 92 mm, the side taken from the opening to the basal angle measures 160 mm. The shape of the siphonal cartilage is ovate, with its anterior end pointed. Its length is 105 mm and it is about half as long as the mantle cartilage.

*Arms*.:—As the epidermis is torn off, the swimming webs and the protecting membranes can not be recognized. Only along the outer side of the right third arm the trace of the keel of the web can be observed. From a few remaining suckers on the arms we conclude that these are arranged in two rows. These suckers are semi-spherical in shape, and with slender pedicels. Nothing definite can be said of the number, the size and the structure of the horny rings, since in most of them even the traces of the pedicels can not be discerned. But as all the arms are preserved to their tips, the following measurements of their lengths are taken:

	Right arms.	Left arms.
I	480 mm.....	450 mm.
II	670 mm.....	580 mm.
III	610 mm.....	650 mm.
IV	710 mm.....	740 mm.

*Tentacles*.:—As the tentacles are relatively better preserved than other parts of the animal, excepting that the epidermis is worn off, a description of their more important structures can be given. Their entire length

is 1460 mm left, and 1420 mm right respectively, of which the club on the left measures 230 mm, and on the right 205 mm, i. e. about  $\frac{1}{6}$  on the left and  $\frac{1}{7}$  on the right. The section of the stalks is rectangular, their breadth and depth are as follows:—

	Left tentacle.		Right tentacle.	
	Breadth.	Depth.	Breadth.	Depth.
At the base.....	35 mm.	20 mm.	37 mm.	15 mm.
At the middle portion	22 mm.	12 mm.	23 mm.	10 mm.

The oral side of the club is flattened, with traces of the protecting membranes on both sides. A trace of web running along the ridge is to be observed on its outer side.

The pads and suckers on the carpal portion are arranged in an oval area of 26 mm in length and 15 mm in breadth, on both tentacles. No trace of a membrane is to be seen surrounding the area. The pads and suckers are arranged in six oblique rows beginning with the ventral ones and ending with the dorsal. These have the same arrangement on the right and on the left, alternating with each other as follows:—

The relative positions of pads (P) and suckers (S) as observed from ventral ones obliquely dorsalwards:—

Left.				Right.		
P.	S.	P.		S.	P.	S.
S.	S.	S.		P.	P.	P.
P.	P.	P.	P.	S.	S.	S.
S.	S.	S.	S.	P.	P.	P.
P.	P.	P.		S.	S.	S.
S.	P.	S.		P.	S.	P.

Moreover, there is an extra pad dorsal to the fifth, and an extra sucker dorsal to the sixth oblique row on the left, and on the right an extra pad between the pad and the sucker on the top of the sixth row. Eighteen pairs of hooks are counted on the hand portion. These are arranged in two rows, but only the seventh which is 9 mm long, and the eighth which is 10 mm long, remain on the left tentacle; and on the right the sixteenth which is 10 mm long, and the eleventh which is 8 mm long. These remaining hooks and the traces of lost ones show, that the hooks of the

ventral row are larger than those of the dorsal, and that the eighth, the ninth, and the tenth hooks are the largest in the same row, while their sizes diminish gradually from the seventh proximally, but suddenly from the eleventh distally.

The distal portion of the club is flattened from side to side and assumes a spatula-like shape. This portion is 4 mm long, and 3 mm wide at the tip, and 2.5 mm wide at the base. It appears that the inner surface of this portion is beset with suckers, of which nine pedicels remain to be recognized.

From the above, imperfect as they are, we can formulate the following characters which are common to the present form, and the similar animals described by DALL-VERRILL and THOMPSON:—

1. The eye-lid has a distinct sinus placed subventrally. In DALL's figure the sinus is placed in the line passing through the middle of the eye, which is most probably to be taken as an error in his sketch.
2. The suckers on the sessile arms are arranged in two rows.
3. The tentacular club consists of a carpal portion with a group of pads and suckers arranged elliptically, a hand portion with two rows of hooks, and a distal portion with small suckers.
4. No nape fold, but with three pairs of folds on the throat.
5. The mantle cartilage is a linear ridge and is twice as long as the siphonal cartilage.
6. The under-skin of the mantle shows the plastered structure.
7. There is a distinct groove on the mid-dorsal line of the mantle.

All these characters combined show without doubt that the present form belongs to the genus *Moroteuthis* in the family *Onchoteuthidae*. Of this genus only two species have so far been known, *M. robusta* (DALL) and *M. ingens* (E. A. SMITH). That it is not *M. ingens* can be seen from the size of the animal as well as from the shape of the mantle and the fins. Of *M. robusta*, we know that only four specimens have up till now been examined. Three of these were discovered by D. H. DALL near Iliuliuk, Uralaska Island, off the coast of Alaska on the 26th of April and 8th of May, 1872. DALL

made sketches and measurements of the specimens; these were described by D. E. VERRILL under the name of *Ommastrephes robustus* in 1876. The fourth specimen, also obtained from the same locality, is described by D'ARCHY THOMPSON by the name of *Ancistroteuthis robusta* (DALL).

The large size of the animal, the general shape of the mantle and the fins, and the locality where the four specimens were obtained, lead us to think, that our specimen is identical with *M. robusta*. As, however, all the specimens obtained from Unalaska were found on the beach, and more or less decomposed and broken, it is very difficult to identify our form which, as stated above, is also in very poor condition, with those described by the above authors. The following comparison between the four specimens and ours will perhaps help us to form a judgement about their specific identification:—

1. The length of the animals:

DALL's specimen.....	No. 1.....	1168 mm <sup>1</sup> .
„ „ .....	No. 2.....	1550 mm.
„ „ .....	No. 3.....	2324 mm.
THOMPSON's specimen.....		1575 mm <sup>1</sup> .
Our specimen.....		1220 mm <sup>2</sup> .

2. The length of the mantle and the attachment of the fin to the same:—

	Length of the mantle:	Length of the attachment of the fin:	Length of the attachment of the fin in % of that of the mantle:
DALL's specimen No. 1.....	1168 mm	?	?
„ „ No. 2.....	1550 mm	857 mm	55 %
„ „ No. 3.....	2324 mm	1219 mm.	52 %
THOMPSON's specimen.....	1575 mm	863 mm	55 %
Our specimen.....	1220 mm <sup>2</sup>	610 mm	50 %

3. The form of the fin in the present specimen lies somewhat between that sketched by DALL (Figs. 1 and 2, Plate XXIII) and that described by THOMPSON, but much nearer to the latter. The broadest portion

1. The figures given by DALL and THOMPSON in inches are estimated in millimetres.

2. Approximately, as stated above.



of the fins described by THOMPSON and that of our specimen lies far more forwards than in that sketched by DALL. Whether this latter is the exact copy of the specimen is perhaps doubtful, and may probably be considered as an error, just as with the position of the sinus of the eye-lid as above stated.

4. From the descriptions and sketches given by DALL, VERRILL and THOMPSON, the shape of the mantle of the four specimens coincides in general with that of our specimen, slight differences in the proportional length and the breadth are to be accounted for partly as individual variations, and partly by the condition of the animals at the time of observation.

5. The armature of the tentacular club. In DALL's specimens the tentacular clubs were wanting, but THOMPSON gives a good figure and a detailed description of the right club, from which we can conclude that the present specimen has the same structure as that of THOMPSON'S. An interesting point about them is that the arrangement of the connective organs in the carpal portion of the right tentacle in THOMPSON'S specimen exactly corresponds with that of the left club of our specimen, except that in the second oblique row there is one sucker less in his specimen than in ours. The arrangements of the connecting organs in his specimen and in ours can be compared thus:—

## THOMPSON'S specimen.

## Right club.

P. S. P.

S. S. S. S.

P. P. P. P.

S. S. S. S.

P. P. P.

S. P. S.

## Our specimen.

## Right club.

S. P. S.

P. P. P.

S. S. S. S.

P. P. P. P.

S. S. S.

P. S. P.

## Left club.

P. S. P.

S. S. S.

P. P. P. P.

S. S. S. S.

P. P. P.

S. P. S.

This reversion of right and left between our specimen and that of THOMPSON'S is perhaps better to be accounted for as individual variations than as a specific distinction between the two specimens.

6. The question of the locality. That there is a close similarity in the marine fauna of the coast of Unalaska and of the Pacific coast near the Tugaru strait, can be conjectured by the relative position of the two

localities; among many animals and plants common in these waters we can cite for instance the gigantic octopod, *Polypus punctatus*.

All these points taken together make us believe that the present form is synonymous with *Moroteuthis robusta* observed and described by DALL, VERRILL and THOMPSON. In this case it forms the fifth example of this interesting species of *Oegopsida* hitherto described.

#### Literature cited.

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#### EXPLANATION OF PLATES.

##### PLATE XLIII.

##### *Moroteuthis robusta*.

All Figures reduced to about  $\frac{1}{3}$  nat. size. A meter scale is given on the left side of the plate.

Fig. 1. Right tentacle and the tip of the left.

Fig. 2. Dorsal view of the mantle with siphon projecting out of the mantle orifice. A median furrow is plainly seen on the anterior portion.

Fig. 3. Dorsal view of the head with arms.

Fig. 4. Dorsal view of the fins.

## PLATE XLIV.

*Moroteuthis robusta.*

In this plate the Figure 7 is a photographic reproduction, all the others drawn from nature by Mr. K. Yokoyama.

Fig. 5. Ventral view of the siphon laid open; the valve, and a trace of the attachment of the central siphonal organ are seen.  $\frac{1}{2}$  nat. size.

Fig. 6. Siphonal cartilage.  $\frac{1}{2}$  nat. size.

Fig. 7. A piece of the dermis taken from the anterior portion of the mantle on the left side. Nearly natural size.

Fig. 8. Left tentacle showing fixing apparatus and hooks.  $\frac{2}{3}$  natural size.

Fig. 8. a. Terminal flattened area of the tentacle showing nine pedicels of suckers. Magnified about 3 diameters.

Fig. 9. A small portion of the right tentacle, showing the fixing apparatus and five pedicels of the proximal suckers.  $\frac{2}{3}$  nat. size.

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Fig. 5.



Fig. 8.

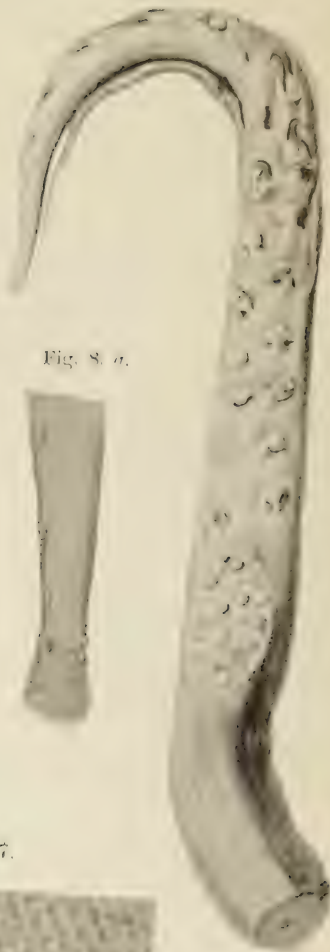


Fig. 8. a.



Fig. 7.



Fig. 9.



Fig. 6.



Fig. 7 photographed by Mr. Fukuhara, Figures 5, 6, 8 and 9. drawn by Mr. K. Yokoyama from nature.





# On a New Species of *Moroteuthis* from the Bay of Sagami, *M. Lönnbergii*.

BY

C. Ishikawa and Y. Wakiya.

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With Plates XLV and XLVI.

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The mantle is, roughly speaking, an elongated retort; somewhat narrow and cylindrical at the entrance, bulging out gradually from about one-fourth to one-third from the orifice, the broadest part lying at about the anterior one-third. From this point it first gradually narrows till about the anterior edge of the attachment of the fins, whence posteriorly it tapers rather suddenly, the posterior one-fourth forming nearly a straight tube. It is also cylindrical near its orifice, becoming flattened posteriorly.

The anterior edge of the mantle shows a conical projection on the mid-dorsal line, flanking on both sides with a slight concavity to the lateral angular projections. The ventral edge of the mantle is rather deeply concave, the perpendicular of the deepest median portion of the concavity being nearly one-fourth the distance between the angular projections.

The actual lengths and the circumferences of the mantle of five specimens measured are as follows:—

No. of Specimens.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Length of the mantle .....	192mm.	147mm.	183mm.	185mm.	275mm.
Circumference at its orifice....	125mm.	105mm.	115mm.	115mm.	165mm.
Circumference at the anterior extremity of the attach- ment of the fin.....	87mm.	72mm.	90mm.	87mm.	130mm.

The surface of the mantle and the head as well as the aboral surface of the basal portion of the arms show the warty appearance characteristic

of the genus. On the mantle this appearance is caused by longitudinal elevations of the dermis, which are about 0.3–0.8 mm in diameter, and anastomosing one another by branches placed obliquely, leaving elongated depressions. These depressions are, for the most part, nearly of the same diameter as the elevations between them, but sometimes broader. The structure of the dermis on the head differs in this that the elevations are in form of semi-spheres of about 0.5–0.6mm in diameter placed close together, giving an appearance like that of shagreen.

It is to be remarked, however, that these elevations and depressions differ considerably according to the state of preservation of the animals. Thus in one specimen the elevations on the mantle are more or less in the shape of polygons, giving the appearance of a reticulated structure, while in others, the elevations seem to be contracted into numerous semi-spherical nodules, which give to the surface an appearance like that we find on the head.

The fins are of an elongated rhomboidal shape, the anterior end of each forming a free rounded lobe and inserted a little on the side of the median line: the inner posterior angle of the lobe is turned slightly medianwards. The distance between the lobes equals about two-fifths of the mantle diameter at the corresponding place. The length of the fin is a little longer than half the length of the mantle. The greatest breadth across the lateral angles is a little less than its length taken from the base of the anterior lobe to its extremity. The lateral angles are broadly rounded, and lie in a line at about one-fifth of the length of the fin. The antero-lateral margin is slightly convex, the postero-lateral also convex, but with a slight concavity along the middle portion, becoming convex again posteriorly, and ends on the dorso-lateral side of the mantle a little in front of its extremity.

The actual measurements of the fins in the five specimens are as follows:—

No. of Specimens.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5
Mantle length.....	192mm.	147mm.	183mm.	185mm.	275mm.
Length of the fin.....	105mm.	81mm.	100mm.	97mm.	149mm.
Length of the fin in % of the mantle length.....	54%	55%	54%	52%	54%

No. of Specimens.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Length of the line of attachment of the fin.....	95mm.	73mm.	92mm.	88mm.	141mm.
Breadth of the fin across the lateral angles.....	98mm.	83mm.	100mm.	97mm.	132mm.
Breadth of the fin in % of the mantle length.....	49%	55%	54%	52%	48%
Distance from the posterior end of the fin to the line across the lateral angles.....	68mm.	56mm.	63mm.	70mm.	106mm.

The siphonal groove is large and tolerably deep, with a distinct ridge along its side, which posteriorly becomes confluent with the ventral longitudinal fold of the neck. Anteriorly the edge of the groove becomes continuous with the general ventral surface of the head, each anterior end of the groove being represented by a rounded depression separated by a flattened ridge, the surface of which being continuous with the general ventral surface of the head. This ridge soon bifurcates with a rounded angle, and runs posteriorly on each side parallel with the lateral margins of the groove as a narrow ridge to the base of the groove. The siphon is rather broad, narrow anteriorly, with a large transverse orifice; the siphonal organ is large and conspicuous, the median unpaired piece is of an arrow-head shape, the posterior end of the arms extending out of the postero-ventral margin of the siphon; the lateral pieces are long-ovate, its anterior portion slightly broader than its posterior, and its diameter a little less than its length.

The siphonal cartilage is somewhat broader posteriorly, the inner margin nearly straight, while the outer margin bulges out slightly near the anterior third, then showing a slight and gradual curvature, again bulging out at the posterior end. The diameter near the posterior end equals a little less than one-third of the length, and about three-fourths of the diameter near the anterior end. The groove is broad and shallow, and of a similar shape to that of the cartilage itself; its inner edge deepens rather abruptly, becoming gradually shallow outward. The mantle is represented by a long linear ridge, fading out posteriorly; its length is nearly one and one half that of the siphonal cartilage.

The actual measurements of the siphon in our specimens Nos. 1 and 2 are as follows:—

Mantle length.	No. of Specimens.	
	No. 1.	No. 2.
Length of the siphon along the side.....	38 mm.	37.0 mm.
Length in mid-ventral line.....		
Length of the siphonal cartilage.	23 mm.	22.5 mm.
	24 mm.	23.0 mm.

The head is rather short, narrower than the mantle orifice; the dorsal surface is slightly convex, the ventral surface is less so, the median line of the latter more or less flattened. The dorso-ventral diameter of the head nearly equals the diameter between the upper margin of the eyes, which is greater than the length. The orifice of the eye not very large, a deep sinus near the base of the lid. The buccal membrane with seven points, seven fastenings and six pores; the inner surface with longitudinal folds.

The actual measurements of the head of the five specimens are as follows:—

No. of Specimens.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Length, dorsal surface.....	29 mm.	24 mm.	25 mm.	25 mm.	30 mm.
Length, ventral surface.....	17 mm.	11 mm.	14 mm.	13 mm.	17 mm.
Breadth between the eyes...	32 mm.	27 mm.	30 mm.	30 mm.	37 mm.
Thickness.....	34 mm.	27 mm.	31 mm.	31 mm.	38 mm.

The posterior margin of the head is produced posteriorly in form of a broad triangular process in the median line, whence laterally it runs more or less in a wavy line till to the anterior end of the third longitudinal fold of the neck, which is situated in a line passing through the middle of the eye lid. The continuation of this marginal line also shows a wavy outline, the anterior ends of the first, the second and the third longitudinal folds of the neck lying at the bottom of the waves, if the head of the animal is placed away from the observer. The entire margin, though very distinct, specially by the difference in colour between the head and the neck, does not show any well defined ridge which fades away near the base of the first longitudinal fold. This fold which is as said before, continuous



with the edge of the siphonal groove, forms an obtuse, more or less rounded angle with it. It is a membranous piece and runs obliquely caudo-dorsalward; its antero-inferior portion is rather high, gradually becoming low and insignificant, and ends near the median portion of the second fold. This fold begins with a slight notch from the posterior margin of the head, in the line passing through the dorsal base of the fourth arm, i.e. a little ventral to the level of the lower eye-lid. It is larger than the first, but runs nearly in the same direction with it; its posterior margin is rounded, but not quite uniform, being interrupted by an olfactory lobe. The third fold begins in the line passing through the middle of the eye-lid, a little above the sinus, where the margin of the head makes an angular projection caudalwards with which the fold joins the same. It is the largest of the three, having a similar shape to that of the second. The line of attachment of the fold on the side of the neck differs, however, a little from that of the second. While, for the ventral half, it runs obliquely dorsalward, its postero-dorsal half runs transversally to the neck, with the dorsal end more or less curved anteriorly. The dorsal end of the third fold lies in a line somewhat ventral to the line between the first and the second arms. The posterior half of the fold then gives the appearance of being a part of the posterior circular fold of the neck. No fold can be seen on the nape.

The arms are subequal in length, the first is the shortest, then comes the third, while the second and the fourth are sometimes of the same and sometimes of different lengths, but are always longer than the third. The actual measurements of the arms of our specimens are as follows:—

No. of Specimens.	No. 1.	No. 2.	No. 3. <sup>1</sup>	No. 4. <sup>2</sup>	No. 5.
Length of the mantle.....	192mm.	147mm.	183mm.	185mm.	275mm.
Length of the 1st arm...{left	125mm.	111 <sup>1</sup> mm.	122mm.	102mm.	145mm.
{right	120mm.	95 <sup>1</sup> mm.	125mm.	102mm.	135mm.
Length of the 2nd arm..{left	112 <sup>1</sup> mm.	136mm.	143mm.	128mm.	185mm.
{right	139mm.	131mm.	120 <sup>1</sup> mm.	125mm.	175mm.

<sup>1</sup> Tip of the arm is lost.

<sup>2</sup> The arms of the specimen No. 4 are strongly contracted owing to the condition of preservation.

No. of Specimens.		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Length of the 3rd arm...	left	132mm.	120mm.	107 <sup>1</sup> mm.	120mm.	170mm.
	right	132mm.	113mm.	76 <sup>1</sup> mm.	123mm.	160mm.
Length of the 4th arm...	left	140mm.	131mm.	141mm.	126mm.	196mm.
	right	138mm.	122mm.	143mm.	125mm.	180mm.

The arms are all rather stout, but their distal portion attenuates toward the tip. The first arm shows a low membrane running along the outer margin of the basal portion; it is very distinct at its base where it is continuous with a less developed one on the inner margin of the second arm, and can be traced till about the middle of the length of the arm. A similar membrane is seen on the second arm. It is more developed than that of the first, and can be traced to the tip of the arm, the basal portion of it forming a web between the second and the third arms. The membrane of the third arm is as usual the largest. It begins a little way from the base of the arm slightly ventral (in the body of the animal) to the above stated web which is continuous from the basal portion of the membrane of the second arm, becoming gradually higher till about one-third from the base of the arm, where it is nearly one and a half times as high as the thickness of the arm at the corresponding point. From this point distally it again becomes lower, and can be traced to the extreme tip of the arm. The fourth arm has a well developed membrane on the outer margin along the entire length. At the base it is continuous with the web extending from the outer ventral base of the third arm, and is at its basal portion a little lower than the thickness of the arm. The protecting membranes are similarly developed on all the arms. These are thin membranes nearly equal in height to the entire length of the sucker of the corresponding part and supported by a series of fleshy transverse bands or ridges standing rather obliquely outward from the base of each sucker. These ridges being a little higher than the membrane between them, give a scalloped outline to the margin of the membrane. The suckers on the arms are arranged in two alternating rows. In all the arms the last sucker is the smallest and begins nearly at the same distance from the base; the following suckers become gradually larger, those of the 6th—11th being generally the largest, whence they get again smaller as we

proceed toward the tip of the arm. On the proximal portion the suckers are globular in shape with shorter pedicels, and more widely set, while distally they become more crowded, each sucker somewhat more shallow and with longer and more slender pedicel. The chitinous ring without dentition, the margin standing out like a collar, with very fine denticulation.

The suckers on the arms of one of our specimens (No. 1) are counted as follows:—

	Left	Right
1st arm	46	40
2nd arm	19 <sup>3</sup>	57
3rd arm	51	50
4th arm	56	55

The tentacles are longer than the mantle, their proportional lengths being as follows:—

No. of Specimens.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Left tentacle.....	112 mm.	145 mm.	153 mm.	191 mm.	323 mm.
Right tentacle.....	100 mm.	194 mm.	177 mm.	94 <sup>4</sup> mm.	331 mm.

The basal portion of the stalk of the tentacle is more or less semi-circular, with the flattened dorsal and the rounded ventral surfaces. Distally the inner side of this rounded surface becomes flattened, and the diameter of the tentacle thus becomes more or less triangular, with the inner and the dorsal sides flattened and with the rounded ventral side. Near the carpal portion, the dorsal side also becomes somewhat rounded. A distinct swimming membrane along the outer margin of the stalk extending to near the base of the distal (ventral) hook of the fourth or fifth row on the hand portion of the club. This membrane is not high, but nearly equally developed all along its length. Along the dorso-inner margin of the carpal portion of the club, the inner margin of the dorsal surface becomes raised in form of a distinct ridge, then membranous as it continues to the hand portion, where it ends near the fifth or sixth hook from the base. Another membrane is found on the ventral outer side of

<sup>3</sup> The tip of the arm is torn off.

<sup>4</sup> The right tentacle of this specimen is very much contracted.



the same. This membrane is nearly of the same length as the last, but is more developed, and begins at the ventral inner side of the distal end of the carpal portion, running transversally at first, and then with a broad curve it turns somewhat obliquely toward the ventral outer side, to end at about the seventh hook of the hand whence distally it can be traced along the base of the dorsal hooks to the end of the tentacle as a very low ridge. A similar but more developed membrane is seen along the base of the ventral hooks.

On the dorsal side of the club, midway between the end of the swimming membrane and the above stated membrane along the dorso-inner margin of the distal two-thirds of the club, a third membrane is to be observed. It begins at about the level of the fourth row of hooks and can be traced to the extreme tip of the tentacle, forming the outer edge of the same which is here dorso-ventrally flattened.

The fixing apparatus of the carpal portion consists of a group of pads and suckers, confined in an oval area, and surrounded by a distinct membrane. These, when observed from the ventral proximal one obliquely dorsalwards, are seen to be roughly arranged in six rows, the relative positions of the suckers (S) and pads (P) in the five specimens being arranged as follows:—

		No. of Specimens.				
The fixing apparatus.		No. 1.	No. 2	No. 3.	No. 4	No. 5.
Right.	{	S. P. S.	P. S.	P. S. P.	S. P.	S. P.
		P. P. P.	S. S. S.	S. S. S. S.	P. P. P.	S. S. S.
		S. S. S. S.	P. P. P.	P. P. P. P.	S. S. S. S.	P. P. P. P.
		P. P. P.	S. S. S.	S. P. S.	P. P. P.	S. S. S.
		S. P. S.	P. S. P.		S. P. S.	P. S. P.
Total number of S & P	{	8S 8P	8S 7P	7S 7P	7S 8P	8S 7P
		P. S. P.	S. P.	S. P. S.	S. P.	P. S.
		S. S. S.	P. P. P.	P. P. P. P.	S. S. S.	P. P. P.
		P. P. P. P.	S. S. S. S.	S. S. S. S.	P. P. P. P.	S. S. S. S.
		S. S. S.	P. P. P.	P. S. P.	S. S. S.	P. P. P.
Left.	{	P. S. P.	S. P. S.		P. S. P.	S. P. S.
		8S 8P	7S 7P	8S 7P.	8S 7P	7S 8P



It will be remarked in this counting, that in the most distal row the median one (pad or sucker) is always situated further distally than the outer two, the three elements here forming a triangle.

The hand portion is armed with thirteen pairs of hooks placed obliquely on the inner surface of the tentacles; the distal half of this portion facing gradually towards the dorsal side. The first hook begins either with a ventral or with a dorsal one, and either directly distal or somewhat further away from the fixing apparatus. The hooks are of variable size; the smaller ones have relatively broader bases than the larger, the recurved portion is also longer relatively than the not curved stalk. The first sucker, when a dorsal one, is the smallest, but when it is a ventral one, it is either a little smaller or nearly equal to that of the second in the dorsal row. Of the following pairs those of the ventral row are always larger than the dorsal. The ventral suckers gradually increase in size from the first to the sixth, the seventh, and the eighth, whence distally they become smaller again. Of the dorsal row the hooks become larger till the fourth, the fifth and the sixth, becoming smaller again distally. The difference between the largest and smallest teeth is much greater in those of the ventral than in those of the dorsal row, and while the teeth of both the rows are nearly of equal size at both the extreme ends of the hand, the largest ventral tooth measures about one-half as long as that of the dorsal. The teeth of the ventral row at both the ends also differ in shape, inasmuch as those near the proximal end have broader bases than those placed near the distal end.

At the extreme end of the tentacle, beyond the hooks, there is an area with a group of ten to thirteen suckers. These suckers are not of equal size, some having about twice the diameter of the others, and are arranged roughly in four or five oblique rows in the dorso-ventral direction.

The pen is strongly chitinous; and has almost no free rhachis. The ventral surface of the rhachis is hollowed out in the shape of a semicircle; its median portion is represented by a narrow colorless line, while the two margins are thickened and deeply colored. These margins first diverge very slowly till about one-half from the anterior end of the entire length of the pen, whence they converge gradually to the tubular cone. The

marginal area begins close to the anterior end of the pen, and spreads out horizontally on both sides of the rhachis for the anterior thirds, then it begins to curve downward, the curvature gradually increasing posteriorly. The breadth of the marginal area gradually increases till about the middle of the pen. Posteriorly it decreases gradually till it reaches the cone. As, however, the marginal area curves ventralward the broadest portion of the pen appears to lie at about the middle of its length, when it is viewed either from the dorsal or from the ventral side. The anterior end of the marginal area is nearly uniformly colored, posteriorly it shows a number of deep brown-colored striations running outward and downward. Along the margins of the posterior half of the pen, these striations become, so to speak, collected together and form a strong rod-like rib on each side. The two ribs approach each other and unite to form the posterior lip of the spoon. The posterior end of the rhachis begins to bend toward the ventral side at the dorsal end of the cone, where it unites the above mentioned lateral ribs of the marginal area. The terminal cone is not cylindrical, but is triangular with a narrower dorsal, and broader lateral surfaces. The dorsal surface, which forms the base of the triangle, is not of an equal breadth, but is narrowed both anteriorly and posteriorly. At the anterior end, which is narrower than the posterior, it is continuous with the median posterior end of the rhachis which here becomes broader, the lateral chitinous portions of which becoming, as stated above, united with the margins of the marginal area. The broadest part of the base of the triangle lies at about one-third from the anterior end. The sides of the triangle have also a triangular shape with a long base which is represented by the margin of the dorsal side and with two unequal sides, the one along the posterior limb of the marginal area, and the other represented by the ventral line. This ventral line as well as the dorsal flattened surface of the cone is curved dorsalwards, so that the side view of the cone looks like a slightly bent horn of cattle. The side of the cone is marked with fine striations diverging from the posterior ventral mid-lip of the spoon.

The color of the animal is purple-brown with a yellowish pearly luster; the ventral side lighter.

Of the five animals, we obtained, one was found by C. Ishikawa on the

beach at Hayama, Sagami Bay, most probably thrown away by fishermen, as the animal is not palatable. The four others were caught by fishermen off Misaki Station, also Sagami Bay, at a depth of from four to five hundred fathoms.

The peculiar plastered structure of the dermis, the relative length and the shape of the siphonal and the mantle cartilages, the three longitudinal neck folds; the ventral position of the sinus of the eye-lid; the buccal membrane with seven points and fastenings; six water pores; the presence of a membrane surrounding the fixing apparatus of the carpal portion of the tentacular club; arms with only two rhachial rows of hooks; and the structure of the gladius; all these characters combined show without doubt, that the above described animal belongs to the genus *Moroteuthis*. The only point which apparently does not coincide with this genus is the absence of the furrow on the anterior portion along the middorsal line of the mantle. This is apparently visible in one of the five specimens, but is lacking in four, so that we can safely state that this furrow does not exist in our forms. If we can verify this point on all other specimens of the species, we have to look upon its presence or absence only as specific characters.

As well known, only two species are till now known of the genus *Moroteuthis*, *M. robusta* (DALL) VERRILL, and *M. ingens*. (E. A. SMITH). From *robusta* it differs in the following points: 1) The elevations of the dermis which in *robusta* run more or less obliquely and transversally to the body of the animal, run in our species longitudinally. 2) The posterior end of the fins are produced more strongly in *robusta* than in our species.<sup>5</sup> It will be remarked here that the shape of the fin of our specimens stands between those of *robusta* and *ingens*. 3) The neck-folds are directed obliquely backward in *robusta*, whereas in our species the anterior portions are placed longitudinally. 4) The number of suckers on the fixing apparatus is fewer in our species than in *robusta*, there being 10-11 in the latter and

<sup>5</sup> THOMPSON describes the fins in his specimen as follows: "The broadest part of the fins is about twenty-seven inches from the apex, which they reach, and towards which their trapezoidal outline is sharply narrowed." l. c. p. 992. This corresponds well with what we observed in our specimen of *robusta* (see our paper in this number of the Journal). The different shape of the fins sketched by DALL and given by VERRILL in his Plate is apparently to be ascribed to the erroneous observation of DALL, rather than to true differences existing between them.



7 or 8 in the former. 5) The number of hooks in the hand portion of the tentacle in *robusta* amounts to 18 pairs, whereas in our species only 13 pairs are found. To these we can perhaps mention the gigantic size of *robusta* compared with the present species.

The following points can be enumerated as differences between the present species and *ingens*: 1) The shape of the mantle of our species is rather slender, and is more or less evenly conical, and greatly produced posteriorly; the length of the mantle to its greatest breadth being about 4:1. In *ingens* the mantle is relatively shorter, its length to breadth being about 3:1, and bulges out at near its posterior third, whence it narrows rather abruptly. 2) In *ingens* the elevations of the dermis on the mantle are angular or spherical, the interspaces between them forming a network, whereas in our species, as stated above, these are arranged more or less in longitudinal directions. 3) The posterior end of the inner margin of the ear-lobe at the anterior attachment of the fin is directed outward in *ingens* and inward in our species. 4) The length and the breadth of the fins in percentage to the length of the mantle differs in two species. These are 49-58% and 61-71% in *ingens* and 52-55% and 48-55% in our species. 5) The inner surface of the buccal membrane is beset with large villi in *ingens*, and with longitudinal foldings in our species. 6) The relative length of the arms, of which the third is longer than the second and the fourth in *ingens*, while in our species it is shorter. 7) The number of suckers in the fixing apparatus is 8-13 in *ingens*, and 8 or 7 in our species. 8) The number of suckers on the terminal area of the tentacle is stated to be 13-18 in *ingens*, whereas in our species it is 10-14. And lastly, there are 13-16 pairs of hooks on the hand portion in *ingens*, and 13 pairs in all our five specimens.

These differences may be enumerated as follows:—

	<i>M. ingens.</i>	<i>M. robusta.</i>	<i>Our species.</i>
The shape of the mantle:—	Club-shaped, bulging out at the posterior third.	Evenly conical.	Retort-shaped, bulging out at about the anterior third; narrowed posteriorly.



	<i>M. ingens.</i>	<i>M. robusta.</i>	<i>Our species.</i>
The length of the mantle to its breadth :—	3 : 1. <sup>6</sup>	5 : 1.	4 : 1.
The structure of the mantle :	Plaster-like elevations on the mantle, spherical or transversally elongated. <sup>7</sup>	Plaster-like elevations on the mantle, directed more or less obliquely or transversally.	The elevations on the mantle, directed more or less longitudinally ; those on the head shagreen-like.
The shape of the fins :—	Rhomboidal ; the antero-lateral margins nearly equal to or a little shorter than the postero-lateral, the lateral angles lie therefore nearly in a line passing through the middle of the length of the fins.	Rhomboidal, with the posterior end strongly elongated ; antero-lateral margins nearly 1/2 as long as the postero-lateral ; the lateral angles lie further on the anterior half of the fins. <sup>8</sup>	Rhomboidal, with the posterior end elongated, the antero-lateral margins about 2/3 of the postero-lateral ; the lateral angles lie at about 1/3 of the anterior end of the length of the fins.
The ear-lobe of the fin :—	The posterior end of the inner margin of the ear-lobe is directed outward.	?	The posterior end of the inner margin of the ear-lobe is directed toward the median line of the body.
The length of the fin in % to that of the mantle.	49 58% <sub>0</sub>	56% <sub>0</sub>	52 55% <sub>0</sub>

6) Roughly estimated from the figure given by PFEFFER (Taf. XI).

7) LÖNNBERG describes the plaster-like structure of *ingens* as like the pavement of an old style street. Looking at his figure (Pl. IV) there is an area on the right hand side of the mantle where the elevations are elongated and run transverse to the animal.

8) This is described from a single specimen we observed.

	<i>M. ingens.</i>	<i>M. robusta.</i>	<i>Our species.</i>
The breadth of the fin in % to that of the mantle.	61-71 %	43% <sup>9</sup>	48-55%
The longitudinal neck-folds:—	The anterior portions directed longitudinally to the neck, the posterior portions somewhat obliquely.	All neck-folds directed obliquely backward. <sup>10</sup>	The anterior parts directed more or less obliquely backward; the posterior portions transversally.
The inner surface of the buccal membrane:—	With large villi.	?	With longitudinal foldings.
The relative length of arms:—	2. 3. 4. nearly of equal length, of which 3. somewhat longer, and 1. is the shortest.	2. 3. nearly of equal length; 4. is the longest, and 1. is the shortest.	2. 4. nearly of equal length, 3. is shorter than 2. and 4.; 1. is the shortest.
The number of suckers on the fixing apparatus:—	8-13	10-11 <sup>11</sup>	8 or 7 <sup>13</sup>
The terminal group of suckers of the tentacle:—	13-18	?	10-14
The number of hooks on the hand portion.	Dorsal 13-16 Ventral 13-15	18 pairs <sup>12</sup>	13 pairs.

9) Estimated from the length given by THOMPSON.

10) VERRILL describes them as "three wavy, raised bands or frills, attached at their inner edge passing obliquely backward, on each side" of the neck.

11) In THOMPSON's specimen 11, and in our specimen 10.

12) THOMPSON states in his description that there are "about eighteen pairs" of hooks.

13) When there are seven suckers, there are eight pads, and vice versa.

These are enough points, we think, to consider the present form of *Moroteuthis* as a new species, which we have the honor of dedicating to Professor EINAR LÖNNBERG of Stockholm, not only for his kindness in helping the authors by sending them the necessary literature on the subject, but also for his valuable investigations on the plaster-like structure of the dermis in this genus.

For the three species of *Moroteuthis* we venture to give a short diagnosis in the following lines:—

Mantle evenly conical, posterior end sharply produced; the breadth across the lateral angles of the fins shorter than the length of the same, and nearly equals the distance between the line of the breadth and the apex of the fins along the median line. This line joining the lateral angles lies at about the anterior fourth of the length of the fins. Hooks on the hand portion of the tentacle in eighteen pairs; fixing apparatus with ten to eleven suckers.

*M. robusta* DALL VERILL,

Mantle bulges out at about its anterior third, posterior end sharply produced; the breadth across the lateral angles of the fins nearly equals their length, and lies at about the anterior third. Hooks on the hand portion of the tentacle in thirteen pairs; fixing apparatus with seven or eight suckers.

*M. lönnbergii* ISHIKAWA et WAKIYA.

Mantle bulges out near its posterior third, posterior end not much produced; the breadth across the lateral angles of the fins greater than their length, and lies slightly posterior to the middle of the length. Hooks on the hand portion of the tentacle in thirteen to sixteen pairs; fixing apparatus with eight to thirteen suckers.

*M. ingens* (E. A. SMITH).

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### EXPLANATION OF PLATES.

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#### PLATE XLV.

*Moroteuthis lönnbergii* ISHIKAWA et WAKIYA.

Fig. 1. Female animal, specimen No. 5, ventral view. 1/2 nat. size.

## PLATE XLVI.

*Moroteuthis lönnbergii* ISHIKAWA et WAKIYA.

Fig. 2. Tentacular clubs, specimen No. 4. Fig. 2a, left, oral view; Fig. 2b, right, aboral view. Twice nat. size.

Fig. 3. Head, specimen No. 5, dorsal view, showing the dermal structure. Nat. size.

Fig. 4. Siphon laid open, showing the siphonal organs and the valve. Nat. size.

Fig. 5. Left mantle cartilage. Nat. size.

Fig. 6. Head, ventral view, showing the siphonal groove; the siphon is pushed a little to one side. Nat. size.

Fig. 7. Oral cone with basal portions of the arms, specimen No. 5.  $\frac{2}{3}$  nat. size.

Fig. 8. Head, side view, showing the longitudinal foldings on the neck, specimen No. 4. Nat. size.

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Fig.1.





Fig. 2a.

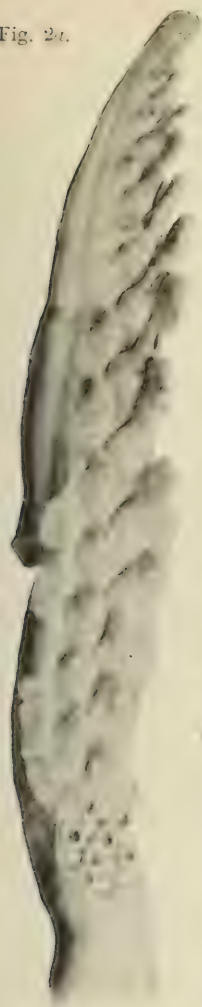


Fig. 4.

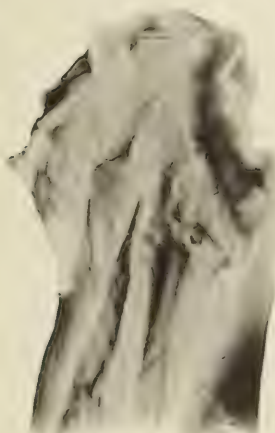


Fig. 3.



Fig. 2b.



Fig. 5.



Fig. 7.



Fig. 6.



Fig. 8.



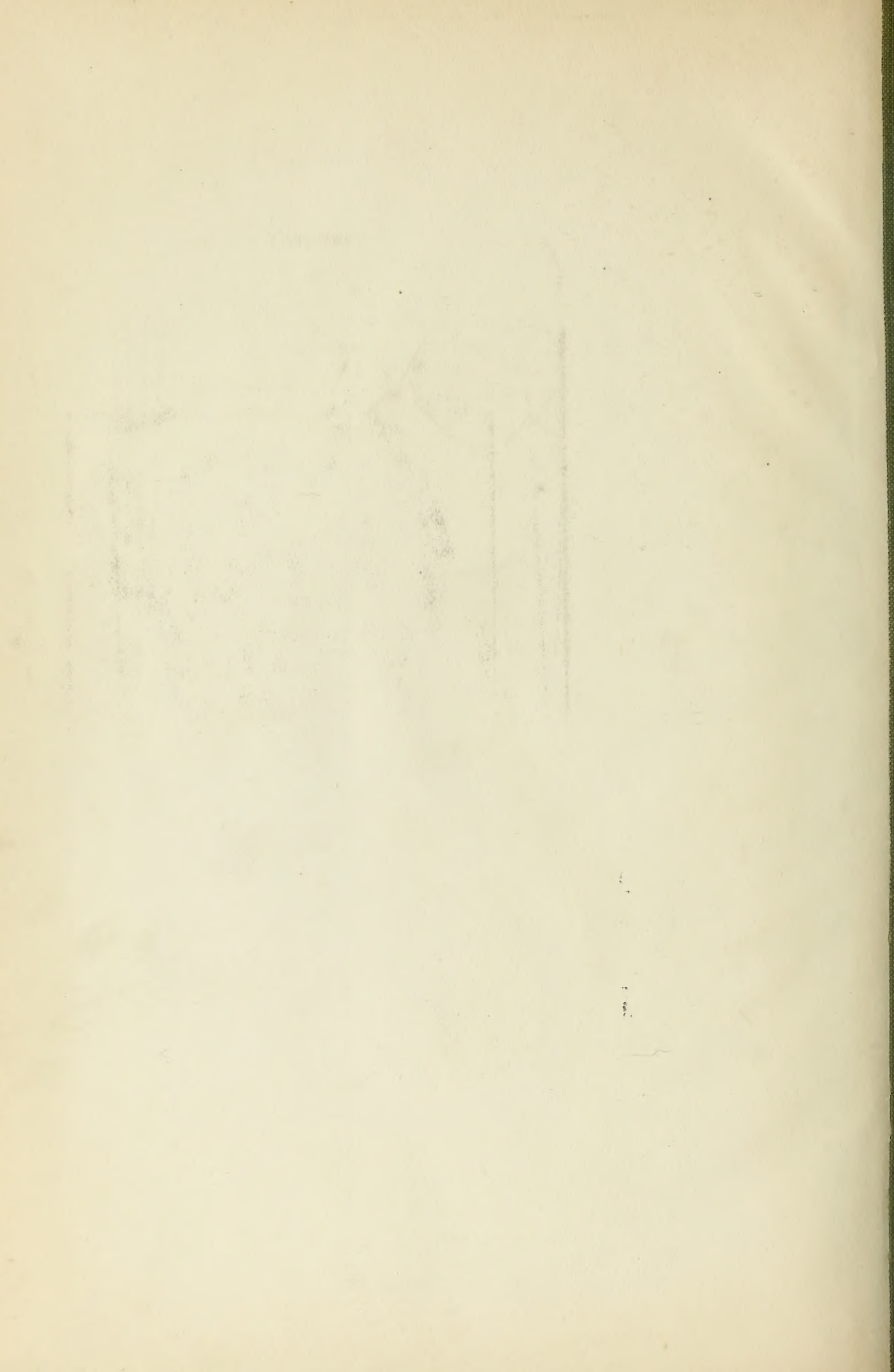














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